

ATOLL RESEARCH BULLETIN

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84. *Atoll News and Comments*



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It is a pleasure to commend the far-sighted policy of the Office of Naval Research, with its emphasis on basic research, as a result of which a grant has made possible the continuation of the Coral Atoll Program of the Pacific Science Board.

It is of interest to note, historically, that much of the fundamental information on atolls of the Pacific was gathered by the U. S. Navy's South Pacific Exploring Expedition, over one hundred years ago, under the command of Captain Charles Wilkes. The continuing nature of such scientific interest by the Navy is shown by the support for the Pacific Science Board's research programs during the past fourteen years.

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THE UNIVERSITY OF CHICAGO

PHYSICS DEPARTMENT

REPORT OF THE PHYSICS DEPARTMENT
FOR THE YEAR 1955-1956

BY THE PHYSICS DEPARTMENT

CHICAGO, ILLINOIS
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PHYSICS DEPARTMENT

Observations on Puluwat and Gaferut, Caroline Islands

by

William A. Niering*

Introduction

Observations presented in this paper were made during the summer of 1954 in conjunction with the Kapingamarangi Expedition to the Caroline Islands**. On the return route to Guam, several other island groups were visited for purposes of comparison. Among these were Puluwat and Gaferut.

I. List of plants noted on Puluwat Islet, Puluwat Atoll

The following species were recorded during a one-hour visit to the islet on Sept. 3, 1954.

Allophylus timorensis Bl.

Occasional in undergrowth.

Artocarpus altilis (Park.) Fosb.

Scattered in interior. Coll. no. 765.

Asplenium nidus L.

Women observed carrying leaves, growing plants not seen.

Calophyllum inophyllum L.

Large trees along lagoon shore.

Canavalia sericea Gray

Frequent in forested and semi-open areas. Coll. no. 769.

Carica papaya L.

Frequent around houses.

Cassytha filiformis L.

Occasional on undergrowth

Cocos nucifera L.

Trees scattered forming open plantations, also young plantings.

Colocasia esculenta (L.) Schott

Important food species.

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** Sponsored by the Pacific Science Board, National Academy of Sciences--National Research Council, and supported by the Office of Naval Research.

Cordia subcordata Lam.

Large specimens along lagoon beach.

Crinum sp.

Profusely flowering along paths.

Cucurbita sp.

Large productive squash in living area.

Eleusine indica (L.) Gaertn.

Frequent in open disturbed sites. Coll. no. 771.

Euphorbia chamissonis Boiss.

Occasional along sandy lagoon beach. Coll. no. 770.

Ficus prolixa Forst.

Coll. no. 767.

F. tinctoria var. neo-ebudarum (Summ.) Fosb.

Coll. no. 766.

Guettarda speciosa L.

Occasional in interior.

Hedyotis biflora (L.) Lam.

Coll. no. 762.

Hibiscus tiliaceus L.

Occasional in understory.

Hymenocallis littoralis (Jacq.) Salisb.

Coll. no. 772.

Ixora sp.

Red flowered ornamental around houses.

Lepturus repens R. Br.

Occasional in disturbed sandy areas.

Messerschmidia argentea (L.f.) Johnst.

Mixed with Scaevola along ocean beach.

Morinda citrifolia L.

Occasional as understory tree.

Musa sp.

Frequent around houses.

Nephrolepis hirsutula (Forst.) Presl

Dominant fern in coconut plantations often forming a dense ground cover 2-3 feet high.

Pandanus tectorius Park.

Frequent, often more common oceanward.

Paspalum conjugatum Berg.

Occasional in open disturbed areas. Coll. no. 763.

Piper betle L.?

Coll. no. 768.

P. fragile Benth.?

Coll. no. 764.

Plumeria rubra L.

Occasional in living area.

Polypodium scolopendria Burm. f.

Frequent on trees, often associated with Nephrolepis.

Portulaca sp.

Yellow flowering form, frequent along and in paths.

Premna obtusifolia R. Br.

Dominant in undergrowth.

Scaevola sericea Vahl

Frequent as a border along beaches.

Stenotaphrum micranthum (Desv.) Hubb.

Frequent in recently cleared areas planted to coconut.

Thalassia hemprichii (Ehrb.) Aschers.

Frequent in shallow sandy lagoon waters.

Thuarea involuta (Forst.) R. & S.

Frequent in recently cleared areas planted to coconut.

Triumfetta procumbens Forst.

Occasional along ocean beach.

Vernonia cinerea (L.) Less.

Weed of open areas.

Wedelia biflora (L.) DC.

Frequent in undergrowth.

Mangrove

Present along south lagoon cove (genus not determined).

II. Description of Gaferut Island

Gaferut Island, an isolated land mass in the northern Carolines, was observed during a brief stop on the morning of Sept. 4, 1954*. The island is approximately 1,500 feet long and 500 feet wide, situated on a somewhat crescent-shaped reef which extends 500-750 feet outward from mean tide level. Gaferut is at present uninhabited, but the Japanese mined phosphatic rock there around 1935. Remnants of their buildings, clearings and excavations can still be seen. About an acre in the interior, although now overgrown, shows evidence of being cleared. In at least four areas excavations were observed, the most extensive being a trench about 2 feet in depth and of considerable width. The other areas within the clearing were quite small.

Geology and Soils

Geologically the island is composed of three types of material: phosphatic rock, coral rubble and sand. The higher interior portion is underlain by phosphatic rock which gives way to a marginal coral rubble border 100 feet or more in width on the east and southeast sides. Along the western shoreline high step-like beach ridges composed of rubble extend 6 feet or more above mean tide level. The sandy deposits form a conspicuous elongated bar extending in a northwesterly direction. Near the end of the sand bar is a very large coral boulder which was probably perched there during a severe storm. These various areas are readily discernable on the aerial photograph (Fig. 1).

The interior phosphatic rock is either exposed, except for blackish algal or fecal coverings, or overlain with a thin rubble soil or humus layer. Several inches of rubble mixed with organic matter are typical. However, in the largest clearing rubble is absent and the rock is overlain by a dark brown friable acid humus (pH 5) varying from 2 to 3 inches in depth. In one area within but near the edge of the clearing it was found to a depth of 6 to 8 inches. These variations in depth may be correlated with the disturbance. One sample from this area contained large quantities of small gastropod shells. Beneath the humus the underlying rock consisted of cemented coral fragments, sand and foraminiferal tests, whereas those from the trench consisted primarily of larger rubble. In both cases the material was similar in that it exhibited a brownish salt and pepper appearance and was relatively soft so that it could be easily broken with one's fingers. In the trench the rock was exposed for at least 2 feet in depth with no evidence of an unconsolidated layer beneath. The humus layer and underlying phosphatic rock have all the characteristics of the Jemo Series named and described by Fosberg (1954) and observed by other investigators (Hatheway 1953, Niering 1956, McKee 1956). Further discussion concerning the possible origin of the rock will follow in a later section.

* The author wishes to acknowledge the most helpful suggestions of Dr. F. Raymond Fosberg and Miss Marie-Hélène Sachet in preparation of this manuscript.

Vegetation and Associated Animal Life

The general vegetational aspect is that of a low, relatively open forest, 12 to 25 feet in height. The dominant tree which characterizes the island is Tournefortia argentea, rather than the coconut which is so typical of inhabited islands. Only two mature coconut trees (Cocos nucifera) 50 to 60 feet in height, probably planted within the last 10 years, were found. The only other woody plant observed was Caesalpinia sp., and it was unimportant. On the phosphatic rock of the interior which has been least disturbed the trees are relatively large and frequently form a continuous but open canopy, in contrast to the marginal rubble borders where the trees are smaller and more scattered. On this coarse marginal rubble the Tournefortia frequently exhibit a shrubby dome-like appearance with branches extending to the ground. In the rubble areas the trees reach 6 to 10 inches in diameter and in the interior sections attain diameters of 12 to 18 inches. The dominant ground cover is Fleurya ruderalis which forms a continuous layer 12 to 18 inches in height in the openings and decreases slightly in the semi-open situations. Several specimens of a cucurbit (Cucurbita sp.) also occurred locally.

Associated with the Tournefortia community is a large bird population including frigate birds (Fregata minor palmerstoni), red footed boobies (Sula sula rubripes), and white terns (Gygis alba candida). Of these the frigate birds are most abundant. Their nests and immature specimens were conspicuous in the trees. At all times the air was filled with the din of hundreds of birds in constant flight. From a kodachrome taken over the island an estimated 550 birds were counted. While walking through the interior one had to be careful of these large birds since one could easily have been hit as they lost altitude on the take-off. Under those trees with many nests the stench was very pronounced and the absence of Fleurya may be correlated with the concentration of guano. It was truly amazing to see such great numbers of birds but presumably this is not atypical of certain uninhabited islands. Pokak, an uninhabited atoll in the Marshalls, is quite similar not only in its large bird population but also in its sparse flora (Fosberg 1957). Here 9 species of vascular plants were found in contrast to 7 on Gaferut.

Associated with the coconut were azure-tailed skinks (Emoia cyanura cyanura) and coconut crabs (Birgus latro). The former were especially abundant in the trees; the latter were found under the fronds on the ground as well as within the nearby herbaceous cover. The largest crabs, one foot or longer, were in the cavities of the rock. Although ten nuts had sprouted under the trees they were partly chewed and the 1 to 2 foot shoots were badly damaged. Whether they will survive is questionable. Other animal life observed included hermit crabs and in the branches of the Tournefortia orb-weaving spiders were common.

In the large clearing toward the south end of the island dense growths of Ipomoea tuba cover most of the opening and are invading the surrounding Tournefortia and forming a complete covering over the trees. Several have already been killed as a result of this invasion. Infesting this viny growth was a caterpillar which develops into a whitish Lepidopteran. Leaves not damaged by this infestation were difficult to find. Another herb found locally in the clearing was Boerhavia diffusa, both the pink and white forms.

At the north end of the island most of the sand bar is devoid of vegetation. However, small Tournefortia are becoming conspicuously established at the south end of the bar. In this sector sea turtle activity was evidenced by the many excavations in the exposed beach sand. Also along the shore a flock of 12 to 15 turnstones (Arenaria interpres interpres) were seen as well as several plovers in flight.

Discussion

The origin of the phosphatic rock is of considerable interest in that it resembles the Jemo Series. The A (humus) and B (rock layer) horizons are comparable but the less consolidated C horizon was not found. Although the greatest depth reported elsewhere for the cemented B layer is $1\frac{1}{2}$ feet, from Jemo Island, this may merely indicate that cementation on Gaferut has taken place to a greater depth. To be associated with the Jemo Series infers a dual biotic relationship only one component of which currently exists on Gaferut - namely, a large bird population. The other facet - a Pisonia forest, is wanting. Could there have been a Pisonia forest in the past - the soil forming processes operative for a long period resulting in the formation of the phosphatic rock and then the forest destroyed by a typhoon? (See section on climate below). Denudation of islands resulting from typhoons has also been reported from Ailinginae and Utirik Atolls in the northern Marshalls (Fosberg 1956) and most recently by Blumenstock (1958) and Fosberg (1961) on Jaluit Atoll in the Marshalls. The small very intensive typhoon which hit Jaluit completely removed the vegetation on the narrower parts of certain islets. Many trees were uprooted or snapped off and washed away. Large Pisonia trees were uprooted, and others still standing had many branches blown off and were greatly defoliated. During the height of the storm wave surges 6 feet in height and locally more than 8 feet swept over the islets accompanied by winds approaching 125 knots (Blumenstock 1958). From these observations it is not unreasonable to assume that a Pisonia forest could have been destroyed on Gaferut (see note on p.13). Surely the very soft nature of the wood would lend itself to tremendous storm damage. Although persisting root systems would tend to produce vigorous root suckers prolonged salt water inundation might well have killed any remaining root systems which were not completely washed away. A small isolated island such as this one would be particularly vulnerable to heavy damage since it would get the full impact of the storm regardless of the direction from which it came. That a severe storm has hit Gaferut is evidenced by a large coral boulder off the north end of the island. Wiens (1959) observed large blocks of this type on Jaluit which were washed 100-300 feet during the typhoon. In addition, the extensively developed marginal rubble border along the east and south sides of the island and the high beach ridges on the west may well have been laid down during such a storm. The fact that phosphatic rock formation does not appear to be occurring at present and has never been reported under Tournefortia suggests that it occurred under a different vegetation type presumably Pisonia grandis.

Although the idea that a severe storm may have destroyed the Pisonia forest is most tenable, its removal by man in clearing the land to facilitate the mining of phosphate is another possibility.

Deleterious effects of the existing bird population were not strikingly evident as has been observed by Hatheway (1955) on Canton Island, where he found dead and dying Tournefortia, presumably associated with the concentrated guano deposits; this is probably correlated with the drier climate of Canton Island in contrast to Gaferut. On Gaferut the larger trees heavily used by birds were not as vigorous in appearance as those in other areas but no dead trees were noted resulting from this factor. However, as mentioned above, the sparsity of herbaceous cover and seedling reproduction may be correlated with excessive guano. Periodic visits by natives may also play some role in reducing the bird population, but their present density would suggest that this influence is negligible.

In interpreting future trends within the existing vegetation it appears that Tournefortia will probably persist as the typical vegetation for some time since there are no other competitive species available which might replace it such as Pisonia or Ochrosia oppositifolia. Whether or not adequate reproduction will occur to replace mature trees in the future is questionable at this point. The two coconut palms that were presumably planted do not appear to be spreading. In fact, the poor vigor of the sprouted nuts as a result of coconut crab activity would suggest that the palm will probably not become an important part of the vegetation. This may well be a limiting factor in the establishment of coconut, even if introduced, on uninhabited islands or those where the coconut crab population is not kept in check. Since the crab is considered such a delicacy by the natives it presents no serious threat on inhabited islands. Another species, Ipomoea tuba, must also be considered since it has already engulfed and killed several Tournefortia. It is not impossible to visualize this very aggressive and drought-resistant species as eventually becoming dominant over an increasingly extensive portion of the interior.

Summary

1. Gaferut, an uninhabited island in the northern Carolines, is dominated by a low forest of Tournefortia argentea. Associated with this community is a large bird population, primarily frigate birds and red footed boobies.
2. The underlying phosphatic rock resembles that of the Jemo Series. Its presence suggests that formerly a Pisonia forest existed on the island and has since been destroyed perhaps by a typhoon. A large coral boulder perched on the reef is indicative of a severe storm in the past.
3. Tournefortia will probably persist as the dominant vegetation for some time. The coconut palms, presumably planted, do not appear to be spreading. Ipomoea tuba which has already killed several Tournefortia may become increasingly important in the future.

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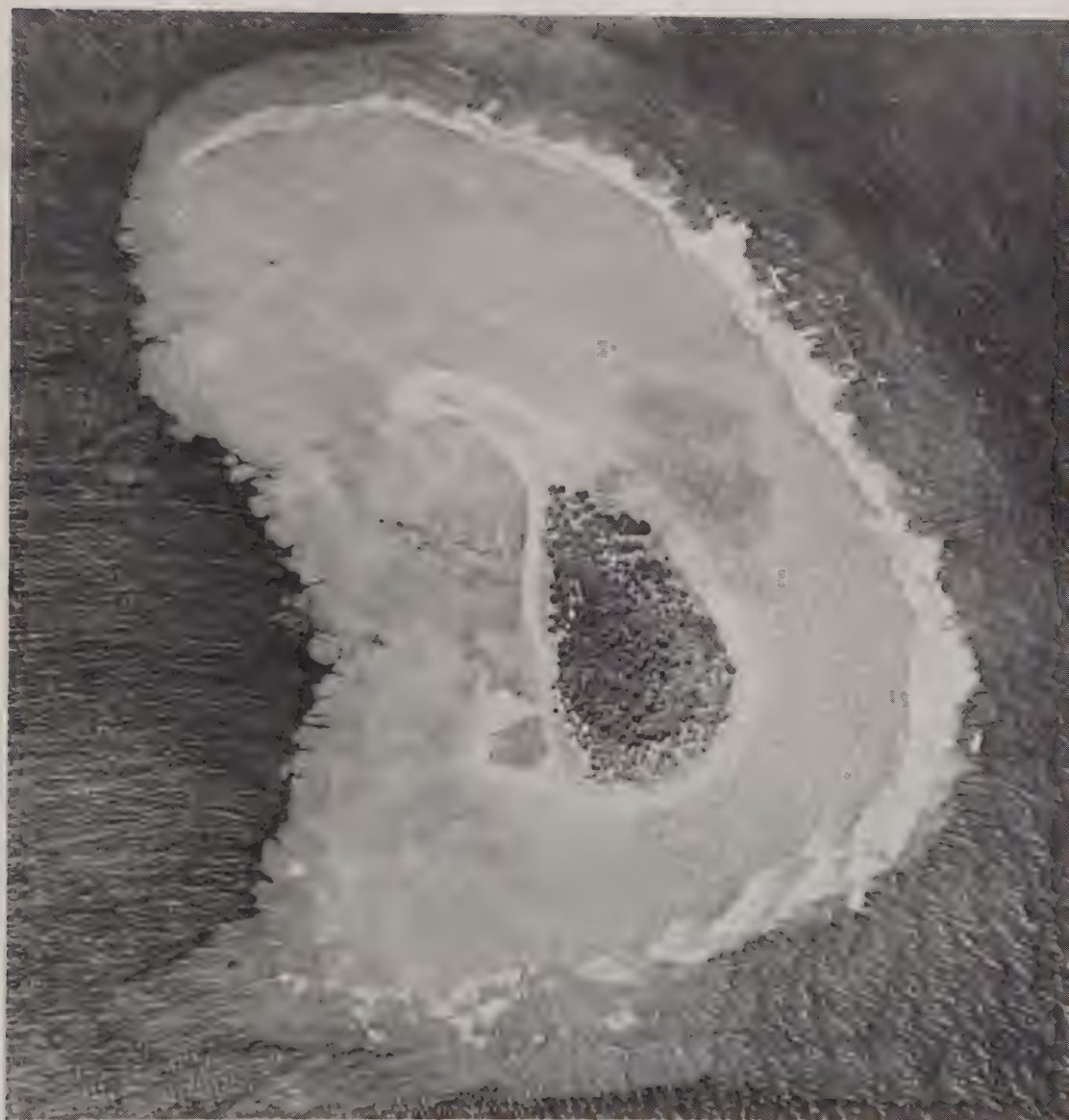
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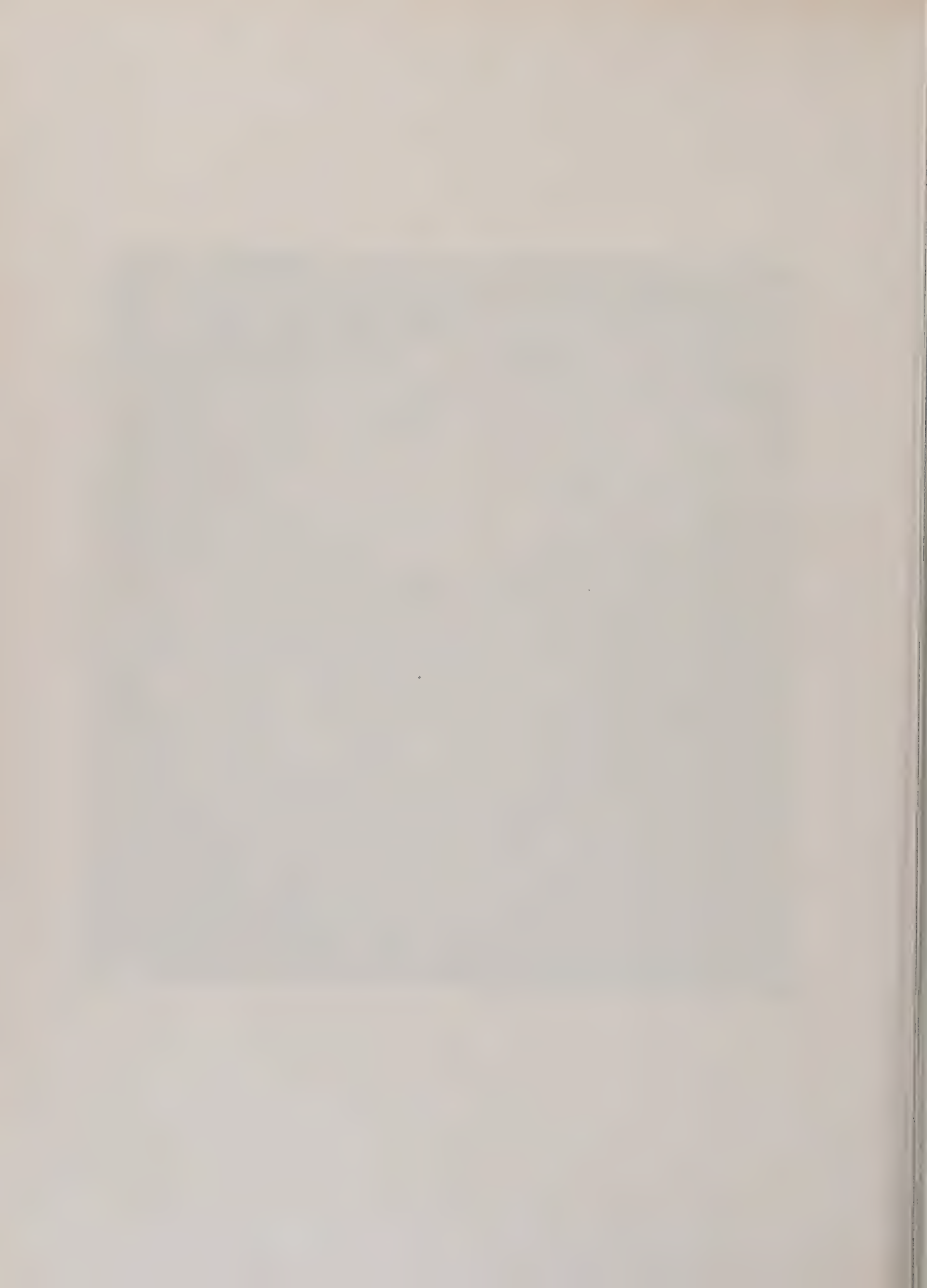
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Annals of the Assoc. of Am. Geographers 49: 31-54, 1959.

Fig. 1 Aerial view of Gaferut Island taken April 1944, 10 years prior to the present observations. Light gray vegetation dominant throughout is Tournefortia argentea. Rubble areas are evident, demarcated by the scattered specimens of Tournefortia, especially on the eastern and southern sides. On the phosphatic rock of the interior, Tournefortia forms a somewhat circular pattern around a uniform darker area which represents the section cleared for phosphate digging. In 1954 the cleared area was dominated by Ipomoea tuba. The sand bar building northwestward is devoid of vegetation. If the coconuts were present at the time the photo was taken, they were too small to be detected. There appears to have been relatively little change in the vegetational pattern in the 10 year period. .

Photo courtesy of U. S. Navy.





Historical and climatic information on Gaferut Island

by

Marie-Hélène Sachet

In view of the scarcity of information on Gaferut, it seemed worthwhile to utilize the library resources of Washington in order to supplement the valuable observations made by Dr. Niering.

History

The real native name of Gaferut is Faiau, Fallao (Spanish spelling), or Fayo (which means stone or rock in the Woleai language of nearby islands). The name Gaferut is never included in the old lists of islands of the Carolines, and, according to Smith (1951, p. 30), is never used by local people. Chamisso (1821, p. 115) relates how Carolinians from Woleai, Lamotrek and other atolls went every spring (April) to Guam, stopping on the way for several days at "Fayo, the desert island," and returning in May or June by the same route. Riesenbergs and Kaneshiro (1960, p. 285) identify this stopping place as Gaferut. Chamisso also discusses some of the early descriptions of these central Caroline atolls and includes a chart modified from Cantova (1728), in which our Gaferut is obviously the island called Fauheu.

Of this island, Chamisso says also (p. 124) that it is uninhabited, without fruit trees or fresh water, which only collects in pits after rain, and that the inhabitants of near-by atolls visit it to collect turtles and birds. Farther on (p. 196) he says that the god of the desert island of Fajo is called Lage, and (p. 205) he writes: "On the desert island of Fajo, as at Bygar [Bikar in the Marshalls], fresh water is conjured into the water pits. There is a species of black-bird [probably the frigate-bird, which was sacred on Sorol and Puluwat] which is under divine protection on this island, and not permitted to be eaten." Chamisso had this information from his friend and informant, Kadu, a native of Woleai.

What then was the real Gaferut? It was either an imaginary magic island, or perhaps a former islet of a reef now devoid of dry land (cf. legend of Ngaruangi in Gressitt 1953, p. 2). According to Krämer (1937, foot-note p. 346) Gaferudj is a name for Sëpen, a former atoll near Yap; Müller (1917, p. 304) mentions that Sepin is a sunken magic island, culturally linked to Rumung (northernmost island of Yap). All this might explain why Senfft (1906, p. 284) was told that Gaferut was a devil's island and never visited by the Caroline people, who were afraid of it. The report then would apply to the real Gaferut, rather than to the island we now know under that name, and which Senfft visited (see below).

The confusion of names was recently clarified by Smith (1951, p. 28) who calls our Gaferut Fayaew (in his own system of phonetic spelling), and adds (p. 29): "'Gaferut' in turn is a bastardization of a Yapese name, even though Yap has only very remote concerns for that island."

Fayaew belongs to the Faraulep people. When the name Gaferut was first applied (or misapplied) to the coral speck in $9^{\circ}14'N$, $145^{\circ}23'E$ has not been ascertained. The island is also called Grimes (Gurimesu-to in Japanese) from Captain Grimes of the ship Jean (Findlay 1870, p. 766), who discovered an island in lat. $9^{\circ}16'N$., long. $145^{\circ}43'E$. He described it as high and well-wooded, of 6 miles in circumference, so there is possibly some confusion with some other island, perhaps Fais. Findlay adds: "It has since been announced as High Island, at lat. $9^{\circ}11'N$., long. $145^{\circ}45'E$" These names are generally considered as synonyms of Gaferut.

One of the few references to Gaferut in the literature is an account of a visit by the German District Administrator of Yap, A. Senfft, in Dec. 1905. He described it (1906) as a flat sand bank, only locally reaching a height of 2 meters. The only vegetation noted was "a species of mangrove." Countless seabirds were nesting in the trees or on the flat ground. Coconut crabs were also observed, and tracks of large sea-turtles. Senfft also noted that a violent storm must have recently hit Gaferut, as most trees had broken branches and some very large ones were completely uprooted. Later, a German expedition exploring for phosphate deposits is said to have discovered phosphate on Gaferut (Aso 1946, p. 117). According to German sources (Sapper 1910) this expedition took place in 1907, not in 1903 as reported in the translation of Aso. As a result of their discoveries, the Germans started exploiting phosphate on Angaur, Peliliu and later Fais, but never on Gaferut. However, the Japanese did mine phosphate there, in spite of great transportation difficulties, starting about 1937.

In addition to the phosphate workers, other Japanese visited Gaferut, among them Yata Haneda, a mycologist interested in luminous fungi, who mentions Gaferut and its phosphate in an account of his 1937 travels in Micronesia (1939). The distinguished geologist Risaburō Tayama apparently also visited Gaferut, and he included a description of it, maps, sections and a photograph in his volumes on coral reefs of Micronesia (1952). He wrote (p. 262): "The table reef of Gaferut is a crude half circle with the convex side facing east. The length of the arc is 1.1 km. Gaferut is the only island on the reef. The shape of the island corresponds roughly to that of the reef. The northern half of the island is chiefly sandy and the southern half primarily gravelly. Recent limestone (Fig. 104) emergent at low tide, is best exposed toward the western end where it strikes northwest and dips 5 to 10 degrees to the southwest. Four recent limestone ridges may be discriminated near the southern coast. The inner ridges are of foraminiferal sandstone and the outer of coral conglomerate; they strike East-West and dip 5 degrees. The central part of the island is flat-topped and rises 5 meters above the reef-flat. The upper surface is level and built of coral limestone (Fig. 105). This limestone is altering to phosphate ore; it conformably overlies a brown clay; and the brown clay, in turn, conformably overlies a foraminiferal sandstone, and the sandstone, the coral gravel and foraminiferal sand bed.

"The reef-flat is extremely wide on the northwest side. The inner zone of the reef-flat is not exposed at low tide, and is dotted with shallow pools about 0.5 meters deep. Seaweeds are growing over the reef floor, and mushroom rocks, 2.5 to 3 meters high, are standing here and there."

Tayama's fig. 103 (p. 116) is a small-scale sketch map with bathymetric contours, and giving 2.7 m as the height of a rock on the NW reef. Fig. 104 (also 146) is a profile of the east coast, from the reef front to the bedded phosphatic rock of the interior, showing a mushroom rock, beach-rock ("recent limestone"), beach sand and gravel between the reef and the phosphate platform. The height of the latter is shown as 5 m above low tide. Fig. 105 is a "Columnar section of beds exposed in pit on Gaferut Island, Gaferut Table Reef," including:

- "a. Surface soil-Blackish brown (20 cm)
- b. Coral limestone-Phosphatic and include abundant Tridacna gigas (35 cm)
- c. Brown clay (25 cm)
- d. Foraminifera limestone-Somewhat phosphatic (65 cm)" lying on
- "e. Foraminifera and coral sand."

An analysis of the "phosphatic reddish brown clay intercalated in the cay sandstone" is given on p. 265:

SiO ₂	CaO	Fe ₂ O ₃	Al ₂ O ₃	P ₂ O ₅
3.28	48.97	3.17	2.50	19.35%

Elsewhere (1942) Tayama had remarked on the amazingly high percentages of silica, iron and aluminum oxides.

In appendix I of the 1952 work is a photo (fig. 48, p. 95) of Gaferut Island. Concerning this F. R. Fosberg says (personal communication): "The presence of bedded phosphate rock on Gaferut suggests that a vegetation of Pisonia grandis may have existed on the island, and the presence of humus on the surface indicates that this must have been in the very recent past. The complete absence of Pisonia now, as indicated by Niering is indeed remarkable. Tayama's photo suggests that Pisonia may possibly have persisted until at least the date of the photo, as the much taller forest on the right side of the picture has the aspect of Pisonia, though the reproduction is so poor that this can be regarded only as an impression rather than a certainty."

There are almost no descriptions of Gaferut in the literature, other than the brief German and Japanese texts. The Sailing Directions (U. S. Hydrographic Office 1938) described it briefly as follows: "low, thickly covered with trees, and encircled by a reef. There are no coconut palms and no inhabitants, but natives from Faraulep Islands visit it to catch birds, which are numerous on it." In a later edition (1952), the information was amended to read: "Gaferut is low and covered with trees. Some of the coconut palms attain a height of 65 feet. There were no permanent inhabitants in 1935, but since that time phosphate mining has been reported. Numerous birds exist on the island, but no food or fresh water."

"The mean high-water interval at the island is 7h. 30m. Mean high-water spring tides rise $2\frac{1}{2}$ feet."

Climate

The climate of Gaferut is a humid tropical one, with little seasonal change. There are no records from the island itself, but in this area of the ocean, temperatures vary little around the year, the mean average air temperature being about 82°F, with daily variations probably not exceeding 15°, and usually less. Atmospheric humidity is always high. It rains throughout the year, with probably higher rainfall in the summer. The total amount of rain must be in the neighborhood of 100 inches (less than Truk to the south and more than Guam to the north). At Lamotrek, somewhat to the south, the rainfall was 104 inches per year, based on 4 years of record.

The wind regime is probably the climatic component most affected by seasonality. The north-east trade winds are rather steady in the winter and spring, and northeast, north and east winds prevail. From June or July to October, the winds are more variable, with often a strong component from southwest, west or south.

Every year some tropical storms or typhoons originate in an area between Gaferut and Truk, and many of them, travelling northwestward toward Guam, must pass near Gaferut. A direct hit is probably not too frequent, but very strong winds and high waves must occur rather often. That Senfft observed the results of the passage of such a storm in 1905 is quite likely. Even Ophelia I, which was so damaging in Jaluit, passed not far from Gaferut toward the end of its destructive career, and so must have Ophelia II (Nov. 30, 1960) which devastated Ulithi. Such storms can occur any month in the year in this part of the Pacific although they are more frequent in the summer and fall.

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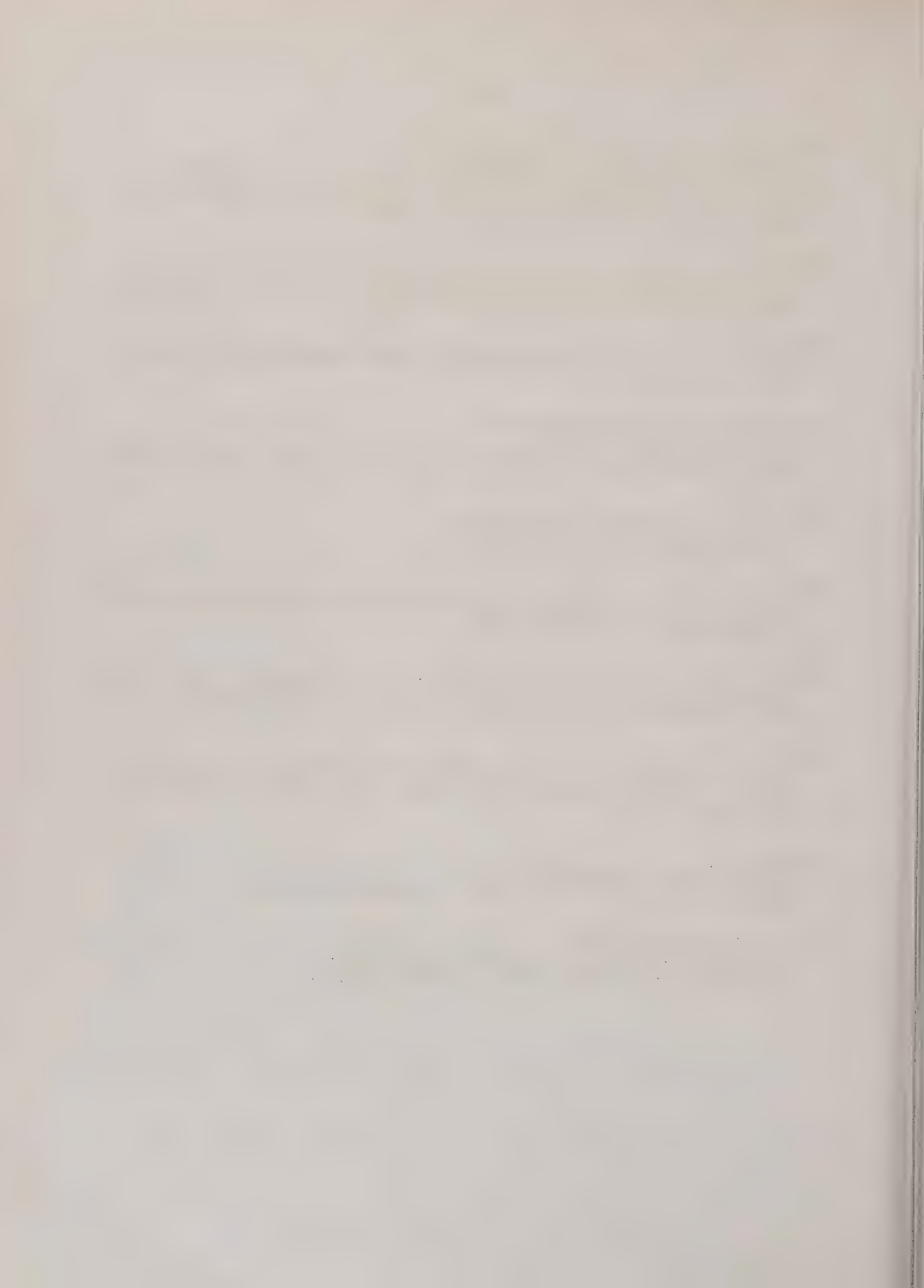
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ATOLL RESEARCH BULLETIN

No. 77

A check list of marine algae from Ifaluk Atoll, Caroline Islands

by

Isabella A. Abbott

Issued by

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National Academy of Sciences--National Research Council

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December 31, 1961



A check list of marine algae from Ifaluk Atoll, Caroline Islands

by Isabella A. Abbott^{1/}

The marine algae of Ifaluk Atoll and of the Caroline Islands in general appear to be similar to those from the Marshall Islands, as described by Taylor (1950) and Dawson (1956, 1957). The Carolines are for the most part low atolls and their algal floras might be expected to be similar. Some of the volcanic islands in the Caroline group should, on the other hand, furnish a more diverse flora.

The present check-list contains algae collected over a four-month period and represents the most intensive collection of algae from the Caroline Islands. It probably includes 80-90% of the algae of a low atoll near the Equator.

There are a total of 54 new records (31 green algae, 1 brown, 22 red) among 85 species reported here for the Caroline Islands. Schmidt (1928) in summarizing the work of earlier investigators, reported a total of 77 species. To this number, about 20 more species have been reported by various Japanese workers in scattered publications.

I wish to thank Dr. Harold J. Coolidge for making possible a grant of funds from Contract N7onr29116 between the Office of Naval Research and the National Academy of Sciences. I am greatly indebted to my husband, Donald P. Abbott, for making these collections for me. The Ifaluk Survey, sponsored by the Pacific Science Board, took place in 1953 and is described by Marston Bates and D. P. Abbott in the volume *Coral Island, Portrait of an Atoll*, Scribner's, 1958.

In the list that follows, algae which were collected at more than 10 stations are listed as very common; those collected at 5-10 stations as common; and those at fewer stations as rare. The specimens have been deposited in the University of Michigan (UM), University of California at Berkeley (UC), Bishop Museum (BM), U.S. National Museum (US), and the Chicago Natural History Museum (CM). Some residual collections are at the Hopkins Marine Station of Stanford University (HMS). An asterisk denotes a new record for the Caroline Islands.

Chlorophyceae

- *Enteromorpha lingulata J. Ag. Rare. HMS
- *Enteromorpha torta (Mertens) Reinbold. Rare. UM, UC, BM, US, CM, HMS.
- *Enteromorpha sp. Common. UM, UC, US, CM.
- *Ulrella lens Crouan. (On Microdictyon okamura). Rare. HMS.
- *Chaetomorpha antennina (Bory) Kützinger. Rare. UM.

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Pacific Grove, Calif.

- *Rhizoclonium samoense Setchell, prox. Rare. HMS.
- Cladophora sp. Very common. UM, UC, HMS.
- *Cladophora fuliginosa Kütz. Common. UM, UC, BM, HMS.
- Valonia aegagropila C. Ag. Very common. UM, UC, BM, US, HMS.
- *Valonia ventricosa J. Ag. Rare. UM, UC, HMS.
- Valonia utricularis C. Ag. Rare. UM, UC, BM, HMS.
- Dictyosphaeria cavernosa (Forssk.) Børg. Very common. UM, UC, BM, US, HMS, CM.
- *Dictyosphaeria versluysii Weber-van Bosse. Very common. UM, UC, BM, US, HMS.
- *Boodlea composita Brand. Very common. UM, UC, BM, US, CM, HMS.
- Anadyomene wrightii Gray. Rare. UM, UC, HMS.
- Microdictyon okamurai Setchell. (The commonest marine alga). UM, UC, BM, US, CM, HMS.
- Caulerpa antoensis Yamada. Very common. UM, UC, BM, US, CM, HMS.
- *Caulerpa ambigua Okamura. Rare. UM.
- *Caulerpa bikiniensis Taylor. Rare. UM.
- Caulerpa serrulata (Forssk.) J. Ag. (and varieties). Very common. UM, UC, BM, US, CM.
- Caulerpa urvilliana Montagne (and forms). Very common. UM, UC, BM, US, HMS, CM.
- *Bryopsis sp. Rare. HMS.
- Udotea argentea Zanardini. Common. UM, UC, BM, US, HMS, CM.
- *Udotea indica A. and E. S. Gepp. Rare. UM, UC, HMS.
- *Udotea orientalis A. and E. S. Gepp. Rare, UM, UC, BM, HMS.
- *Avrainvillea obscura J. Ag. Rare. UM, UC, BM, HMS.
- Avrainvillea sp. UM, UC, CM.

- *Rhipilia diaphana Taylor. Rare. UM.
- *Rhipilia geppii Taylor. Common. UM, UC, BM, US, HMS, CM.
- *Rhipilia orientalis A. and E. S. Gepp. Common. UM, UC, BM, US, HMS.
- *Halimeda fragilis Taylor. Rare. HMS.
- *Halimeda gracilis Harvey (and form). Very common. UM, UC, BM, US, HMS, CM.
- *Halimeda lacunalis Taylor. Rare. UM, UC.
- Halimeda micronesica Yamada. Very common. UM, UC, BM, US, HMS, CM.
- Halimeda opuntia (L.) Lamx. (and forms). Very common. UM, UC, BM, US, HMS, CM. Note: The formae elongata, hederacea, triloba and renschii are distributed between UM, UC, and BM.
- *Halimeda stuposa Taylor. Very common. UM, UC, BM, US, HMS, CM.
- *Halimeda taenicola Taylor. Common. UM, UC, BM, US, HMS.
- Halimeda tridens (Ellis et Sol.) Lamx. Rare. UM, UC.
- Halimeda sp. UM. (7 specimens).
- *Halicoryne wrightii Harvey. Rare. UC.
- *Neomeris annulata Dickie. Rare. HMS.
- *Neomeris vanbosseae Howe. Rare. UM, UC.
- *Acetabularia parvula Solms-Laubach. Common. UM, UC, BM, US, HMS.
- *Vaucheria sp. Rare. HMS.
- *Dichotomosiphon sp. Rare. UM, HMS.
- *Pseudodichotomosiphon constricta Yamada. Rare. UM, UC, BM, HMS.

Phaeophyceae

- *Ectocarpus mitchellae Harvey. Rare. UM, UC.
- Sphacelaria sp. HMS.
- Pocockiella variegata (Lamx.) Papenf. Very common. UM, UC, BM, US, HMS, CM.

Rhodophyceae

- Asterocytis ornata (C. Ag.) Hamel. Rare. UM, UC, US.
- *Goniotrichum elegans (Chauvin) Zanard. Rare. HMS.
- Erythrotrichia carnea (Dillwyn) J. Ag. Rare. UC.
- *Liagora ceranoides Lamx. Rare. UM, UC, BM, US, HMS.
- *Liagora kahukuana Abbott. Rare. UM, UC, BM, US, HMS.
- *Liagora sp. (3 collections). HMS.
- *Galaxaura filamentosa Chou. Rare. UM, UC, HMS.
- Galaxaura fastigiata Decaisne. Rare. UM, HMS.
- *Goniolithon frutescens (Foslie) Foslie. Rare. UM, UC, HMS.
- *Porolithon onkodes (Heydrich) Foslie. Very common. UM, UC, BM, US, HMS, CM.
- *Porolithon gardineri (Foslie) Foslie. Very common. UM, UC, BM, US, HMS.
- *Porolithon aequinoctiale (Foslie) Foslie. Common. UM, UC, BM, US, HMS.
- *Porolithon sp. (4 specimens). UM, UC, BM.
- *Lithothamnion sp. Common. UM, UC, BM, HMS.
- *Fosliella farinosa (Lamx.) Howe. Very common on other algae.
- Jania sp. Very common. UM, UC, BM, US, HMS.
- Hypnea nidulans Setchell. Rare. UM, UC, BM, US, HMS, CM.
- *Hypnea spinella (C. Ag.) Kützinger. Common. UM, UC, BM, US, CM.
- *Wurdemannia miniata (Drap.) Feldmann et Hamel. Rare. HMS.
- *Rhodymenia sp. Rare. HMS.
- *Ceramium sp. Common. UM, UC.
- Centroceras clavulatum (C. Ag.) Montagne. Rare. UC.
- Centroceras minutum Yamada. Common. UM, UC.

- *Antithamnion sp. Rare. HMS.
- *Griffithsia tenuis C. Ag. Rare. HMS.
- *Griffithsia rhizophora (Grun.) Weber-van Bosse. Rare. HMS.
- Haloplegma duperreyi Montagne. Common. UM, UC, BM, US, HMS, CM.
- Heterosiphonia wurdemannii (Bail.) Falkenb. Rare. HMS.
- Dasya adhaerens Yamada. Rare. UM, UC.
- Hypoglossum minimum Yamada. Rare. UM.
- *Polysiphonia subtilissima Montagne. Very common. UM, UC, US, HMS, CM.
- *Herposiphonia tenella (C. Ag.) Naegeli. Very common. UM, UC, BM,
US, HMS.
- Leveilleia jungermannioides (Mart. et Her.) Harvey. Rare: Occurring
on species of Halimeda. UM, UC, BM.
- *Laurencia mariannensis Yamada. Very common. UM, UC, BM, HMS, US.
- Laurencia perforata (Bory) Montagne, prox. Common. UM.
- Laurencia sp. (two specimens). UM.
- Chondria sp. (1 specimen). HMS.

Angiospermae

- Halophila ovalis R. Br. Common. UM, UC, BM, US, HMS.

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ATOLL RESEARCH BULLETIN

No. 78

Narrative report of botanical field work on Kure Island,
3 October 1959 to 9 October 1959

by

Horace F. Clay

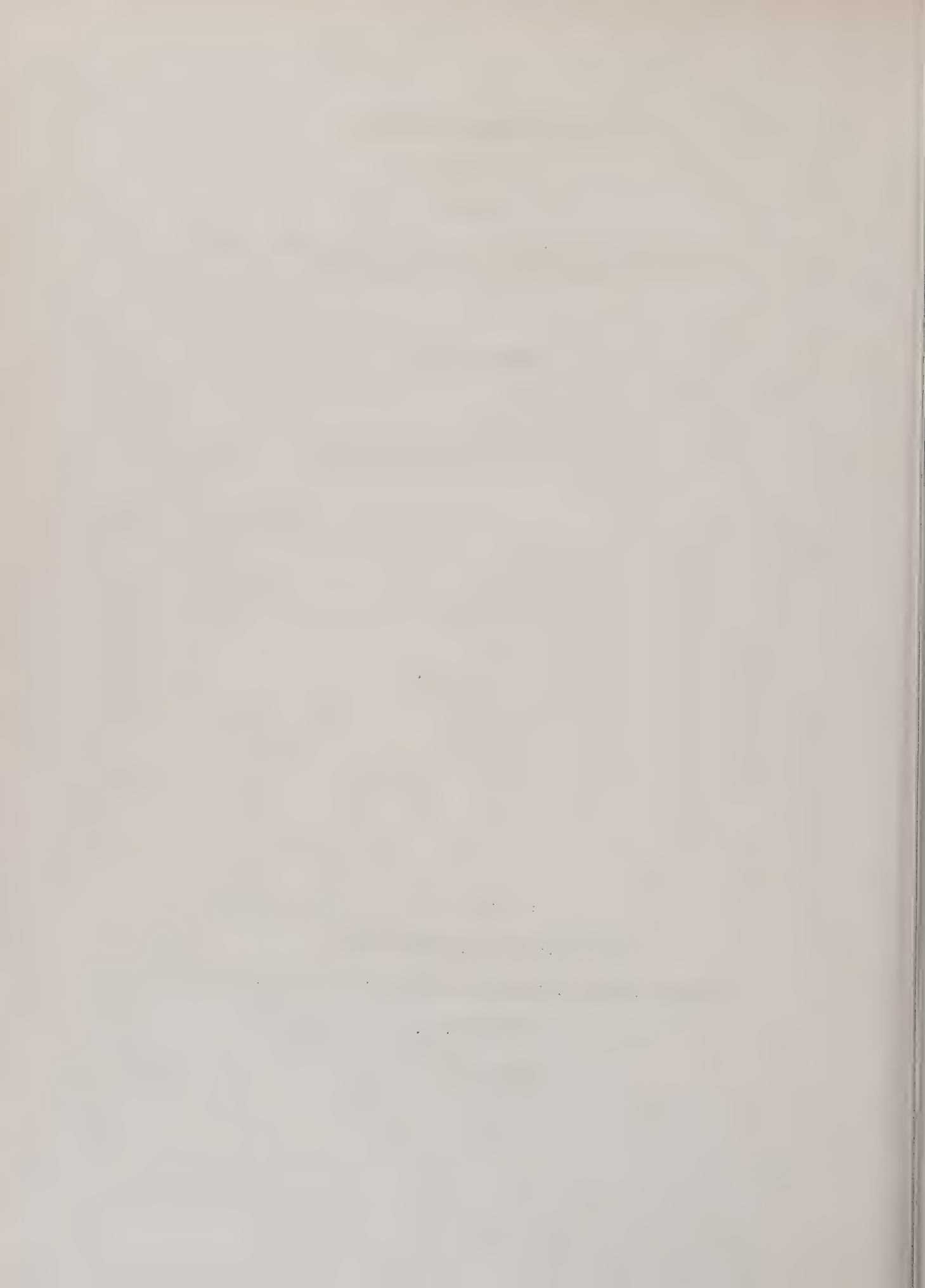
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December 31, 1961



Narrative Report of Botanical Field Work on Kure Island

3 October 1959 to 9 October 1959

by Horace F. Clay
University of Hawaii

Kure (often referred to as Ocean Island) is the most western island in the Hawaiian Archipelago. It is located about 1250 miles west of Honolulu. The atoll is described, with map and bibliography, in E. H. Bryan, Jr., *American Polynesia and the Hawaiian Chain*, Honolulu, 1942.

In order to make Kure Island more habitable to the blackfooted and Laysan Albatrosses, the Naval Construction Forces of the Pacific in October 1959 planned to bulldoze a series of runways 100 yards long and 50 feet wide on Kure Island. This is a report of the botanical field work carried on in conjunction with that Navy project.

The State of Hawaii, through its Land Commissioner, Mr. Eric Reppun, gave the Navy permission (Revocable Permit No. 2580) to make the alterations to Kure Island. The State of Hawaii, however, stipulated that two types of plants be preserved on Kure Island, Lepturus repens and Solanum nelsoni var. intermedium (now Solanum nelsoni). The writer, familiar with atoll floras, was invited to join the group going to Kure, so that identification could be made of the plants growing on that island.

A previous collection of plants had been made by the Tanager Expedition in April 1923. In that year, thirteen species of vascular plants were collected on Kure. Eleven of these thirteen species are still growing there; Cenchrus agrimonioides var. laysanensis and Achyranthes splendens var. reflexa, represented by a very few specimens in 1923, have disappeared*. However, six new species have found their way to Kure, so the flora there now comprises seventeen kinds of plants.

Green Island, the largest of the three islets at Kure Atoll, is the only one on which there is any higher plant life. The other two islets are tiny sand-spits. Green Island is approximately three-fourths of a mile long, about one-half mile wide, and has an elevation of some 20 feet. There is a dense growth of Scaevola sericea which encircles and covers most of Green Island. Scattered here and there among these Scaevola plants are patches of Boerhavia diffusa which sometimes appear as a loose ground cover under the Scaevola and frequently can be seen as scrambling vine-like plants. Sand dunes rise sharply from the beach on the lagoon side, and the Scaevola sericea is less dense here. In the open areas along the dunes, one can observe scattered clumps of the bunch grasses, Eragrostis variabilis and Eragrostis whitneyi var. caumii. On the inner slopes of the dunes near the radar reflector tower, several dozen clumps of Lepturus repens can be found. With the exception of three clumps of this grass on the dunes at the eastern tip of Green Island, Lepturus repens was only observed near the radar reflector tower.

* These two species, while not in evidence in 1959, were found again in 1961 by Ch. Lamoureux, cf. Bulletin 79.

Since Cynodon dactylon, Casuarina equisetifolia (4 of the 6 existing specimens on Green Island), Pluchea odorata and Verbesina encelioides seem to be localized on the dunes near the radar reflector tower which was constructed in 1955, it is surmised that seeds of these plants were brought on equipment from the Island of Midway.

One very young specimen of Messerschmidia argentea, the only one on Green Island, was found growing on the windward shore.

An open plain of about 25 acres comprises the central-eastern portion of the islet. On this plain were found Lepidium owaihiense, Tribulus cistoides, Ipomoea indica, Solanum nelsoni, Solanum nigrum, Sicyos hispidus, and Lipochaeta integrifolia. These plants were only found on the plain and not in any other areas of Green Island.

Two different saprophytic fungi were found, both associated with decaying stems of Scaevola sericea. These fungi have not been identified.

As a matter of interest, during the seven days that the author spent on Kure, seeds were collected in the beach drift. The following were found during this period: Cocos nucifera - 7 dead nuts, Aleurites moluccana - 9 dead nuts, and Mucuna gigantea - 1 seed.

The following is a total list of the plants collected on this expedition. Those marked with an asterisk are new since the Tanager Expedition, April 1923.

*2 Fungi

Gramineae:

*Cynodon dactylon (L.) Pers.

Eragrostis variabilis (Gaud.) Steud.

Eragrostis whitneyi Fosb. var. caumii Fosb. /E. falcata/

Lepturus repens (Forst.) R. Br.

Casuarinaceae:

*Casuarina equisetifolia L.

Nyctaginaceae:

Boerhavia diffusa L.

Cruciferae:

Lepidium owaihiense Cham. & Schlecht.

Zygophyllaceae:

Tribulus cistoides L.

Convolvulaceae:

Ipomoea indica (Burm.) Merr.

Boraginaceae:

*Messerschmidia argentea (L.) Johnston (photo only)

Solanaceae:

Solanum nelsoni Dunal

*Solanum nigrum L.

Cucurbitaceae:

Sicyos hispidus Hbd.

Goodeniaceae:

Scaevola sericea Vahl

Compositae:

Lipochaeta integrifolia (Nutt.) Gray

*Pluchea odorata (L.) Cass.

*Verbesina encelioides Gray

On the beach were found:

Cocos nucifera L., 7 dead nuts

Aleurites moluccana Willd., 9 nuts

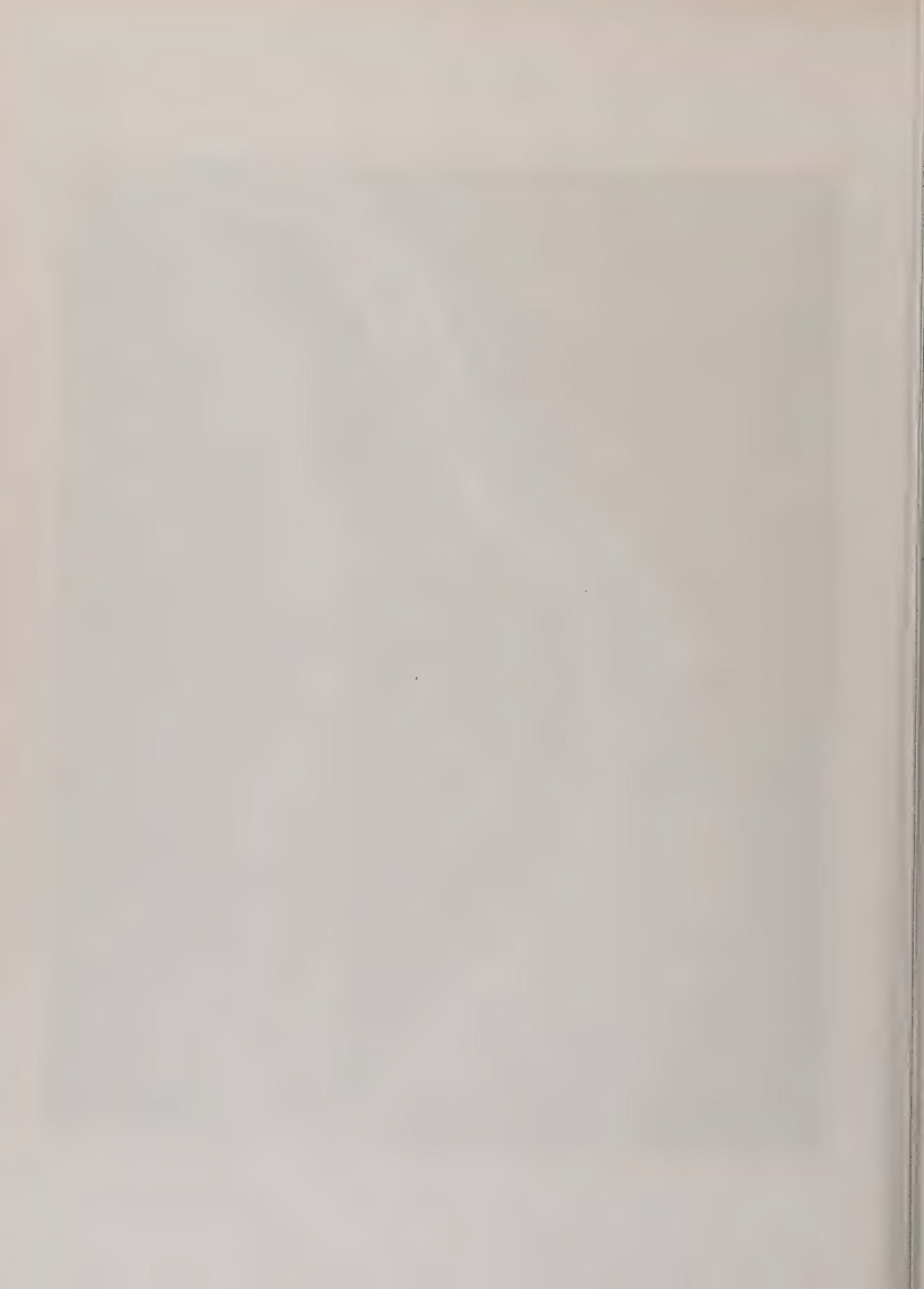
*Mucuna gigantea (Willd.) DC., 1 seed

Herbarium specimens and photographs in the field of the plants collected on this trip are located in the Herbarium of the Bishop Museum, Honolulu, Hawaii, and in the U.S. National Herbarium, Washington, D. C.

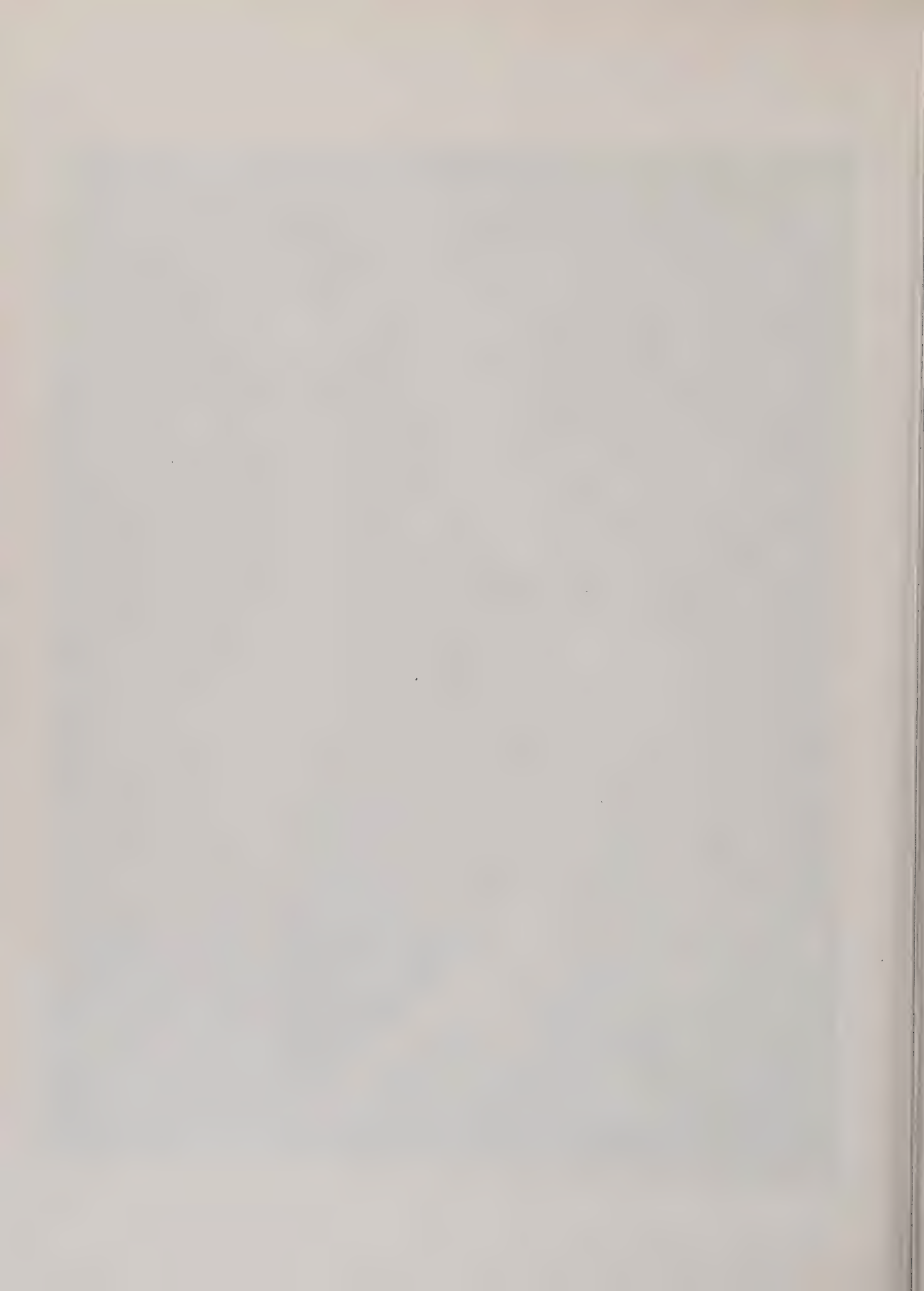
Photos: Green Island, Kure Atoll, from air, October 3 and November 3, 1959, before and after "habitat improvement".

Photos courtesy of U. S. Navy









ATOLL RESEARCH BULLETIN

No. 79

Botanical observations on Leeward Hawaiian Atolls

by

Charles H. Lamoureux

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Botanical Observations on Leeward Hawaiian Atolls

by

Charles H. Lamoureux^{1/}

I. Notes on the plants of Kure Atoll

Through the courtesy of the United States Coast Guard and Dr. H. J. Coolidge, the writer was able to visit Kure Atoll from September 12 to 14, 1961. The observations made at this time will serve as a supplement to Dr. Clay's (see ARB no. 78) report. I wish to thank Drs. George Butler, M. D. F. Udvardy, Robert Usinger, and Mr. David Woodside for calling my attention to certain plants.

Since Dr. H. F. Clay visited Kure in October, 1959, a U. S. Coast Guard Loran Station has been constructed there on Green Island. Among the facilities now present on the island are a landing strip paved with crushed coral over asphalt, a series of buildings and a 625 foot radio tower. As a result of the disturbances caused by activities involved in the construction of these facilities and the intentional and unintentional introduction of plants concomitant with such activities, there have been significant changes in the flora and vegetation of the island within the past two years.

All 13 species of vascular plants collected in 1923 by the Tanager Expedition (Christopherson and Caum, 1931) were still growing on Kure during the present visit in 1961. Of the six species first reported by Clay (ARB 78), all but Pluchea odorata were collected. In addition one presumed native species, Phyllostegia variabilis, and 22 species of newly introduced weeds and cultivated plants are here reported from Kure for the first time. Thus the flora now contains 41 species of vascular plants.

The Commanding officer of the Loran Station informed us that approximately 1500 plants for use in landscaping were flown in from Honolulu in March, 1961. Those which have survived are planted in the clearing around the buildings and the tennis court. In addition, Cynodon dactylon has been planted as a lawn grass and appears to be thriving. Another 200 pounds of seed of this species is being sown to create more lawn area. The introduction of more shade tree species is being considered. Some of the weed species were obviously introduced with the plants from Honolulu since they occur either in the cans with these plants or a short distance from the cans and not elsewhere on the island. Other weedy species are at present restricted to road margins or other disturbed areas and may have come in with some of the heavy construction equipment. One plant of Spergularia marina found growing in the middle of the airstrip may well have developed from a seed transported to Kure in the landing gear of some aircraft. This Spergularia is abundant on the margins of the airstrip at French Frigate Shoal, although it has not been reported from Midway.

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During the stay on Kure the larger of the two sand islands was visited. This island is about 400 meters long, 10 to 20 meters wide and reaches a maximum elevation of about one meter. The vegetation consisted of less than a dozen scattered plants of Boerhavia diffusa and one tiny clump of Eragrostis whitneyi var. caumii. Observation of the smaller sand island (50 m. by 10 m.) from a distance of approximately 50 meters revealed no sign of vascular plants. All other species are restricted to Green Island.

Specimens cited below were collected and identified by the author and have been deposited in the herbarium of the Bernice P. Bishop Museum, Honolulu 17, Hawaii. The initials "CHL" identify the author's collection numbers. No specimens of cultivated plants were made. New records are indicated by *.

PANDANACEAE

*Pandanus sp. Variegated variety planted near the living quarters.

GRAMINEAE

Cenchrus agrimonioides var. laysanensis F. Br. Half a dozen clumps in one small area of the central plain, intermixed with Boerhavia and Scaevola. CHL 1912.

*Cenchrus echinatus L. Two plants observed, one near the living quarters, the other near the east end of the landing strip. Both had set large quantities of seed so this plant will probably spread. CHL 1908.

*Chloris inflata Link. Disturbed areas near quarters and on roadsides. CHL 1907.

*Chloris virgata Swartz. Disturbed areas near quarters. CHL 1887.

Cynodon dactylon (L.) Pers. On dunes and beach near radar reflector tower, and used around quarters as lawn grass. CHL 1866, 1884, 1885.

*Digitaria sanguinalis (L.) Scop. Disturbed areas near quarters. CHL 1864.

*Eleusine indica (L.) Gaertn. Disturbed areas near quarters. CHL 1888.

*Eragrostis amabilis (L.) W. & A. Disturbed areas near quarters. CHL 1862.

Eragrostis variabilis (Gaud.) Steud. Fairly abundant in open areas of eastern-central plain. CHL 1868, 1869.

Eragrostis whitneyi var. caumii Fosb. Common in open sandy areas on lagoon side. One clump on the larger sand island. CHL 1861, 1867, 1870, 1893.

Lepturus repens var. subulatus Fosb. Several clumps near radar reflector tower and near east end of plain. CHL 1873.

*Setaria verticillata (L.) Beauv. One plant near the west end of the landing strip. CHL 1906.

CYPERACEAE

*Cyperus rotundus L. A few plants in disturbed areas near quarters. CHL 1905.

PALMAE

*Cocos nucifera L. Seedlings planted near quarters.

CASUARINACEAE

Casuarina equisetifolia L. In addition to the larger trees reported by Clay (ARB 78), several young plants are being grown around the quarters. CHL 1886.

AMARANTHACEAE

Achyranthes splendens var. reflexa Hbd. Here and there on the central plain. CHL 1875, 1894.

NYCTAGINACEAE

Boerhavia diffusa L. Abundant all over Green Island under and around Scaevola bushes and on the central plain. Boerhavia is growing rapidly in recently cleared areas and has covered the albatross runways which were cleared in October 1959. It is growing through the black-top at the east end of the landing strip. About a dozen plants are growing on the larger sand island. CHL 1860, 1876, 1877, 1881, 1882.

CARYOPHYLLACEAE

*Spergularia marina (L.) Griseb. One plant growing in the center of the landing strip, a few others noted along the road leading to the radio tower. CHL 1910.

CRUCIFERAE

Lepidium o-waihiense C. & S. Abundant on the central plain and invading areas recently cleared for installation of radio tower guy wires. CHL 1872.

ZYGOPHYLLACEAE

Tribulus cistoides L. Here and there in the central plain and on roadsides. CHL 1874.

EUPHORBIACEAE

*Codiaeum sp. Cultivated near quarters.

*Euphorbia glomerifera (Millsp.) Wheeler. Weed in cans with cultivated plants near quarters and spreading into open areas nearby. CHL 1863, 1904.

MALVACEAE

*Hibiscus sp. Cultivated near quarters.

*Thespesia populnea (L.) Sol. Cultivated near quarters.

COMBRETACEAE

*Terminalia catappa L. Cultivated near quarters.

APOCYNACEAE

*Nerium oleander L. Cultivated near quarters.

CONVOLVULACEAE

Ipomoea indica (Burm. f.) Merr. Common on central plain. CHL 1880.

BORAGINACEAE

Messerschmidia argentea (L.f.) Johnston. Several trees near eastern tip of island, one on south-central part. CHL 1895.

LABIATAE

*Phyllostegia variabilis Bitter. Two sterile plants were found on the central plain growing in a patch of Boerhavia diffusa and Solanum nelsoni about 100 meters from the tennis courts. The vegetative characters match those of Phyllostegia variabilis, a species previously recorded only from Laysan and Midway. Certain identification, however, awaits the collection of fertile material. CHL 1926.

SOLANACEAE

Solanum nelsoni Dunal. Common around edges of and occasionally in Scaevola thickets on central plain. CHL 1878, 1879, 1898.

Solanum nigrum L. Common on central plain, especially in disturbed areas. CHL 1897.

CUCURBITACEAE

Sicyos hispidus Hbd. Common on central plain. CHL 1899 - 1903.

GOODENIACEAE

Scaevola sericea Vahl. Abundant all over island forming dense thickets from one to three meters high. CHL 1871, 1890, 1891.

COMPOSITAE

*Conyza bonariensis (L.) Cronq. One clump noted near quarters. CHL 1909.

*Emilia javanica (Burm.) Rob. Weed in cans with cultivated plants near quarters and spreading into open areas nearby. CHL 1864.

*Gnaphalium sandwicense Gaud. Abundant in recently cleared areas around quarters. CHL 1889, 1892.

*Helianthus annuus L. Cultivated near quarters.

Lipochaeta integrifolia (Nutt.) Gray. Common on central plain, moving into disturbed areas. CHL 1911.

*Sonchus oleraceus L. Disturbed areas near quarters. CHL 1883.

Verbesina encelioides (Cav.) B. & H. Several plants near radar reflector tower and spreading onto nearby lagoon beach, with seedlings also present in disturbed areas near quarters. CHL 1896.

The disturbed areas, which are the places where the greatest vegetational changes are to be expected, are of four general types:

- a. Margins of roads and landing strip. Boerhavia diffusa has covered most of the margin of the landing strip, with Tribulus cistoides and some of the weedy grasses occurring as scattered individuals. Along the roadsides Boerhavia is somewhat less abundant with a larger proportion of weeds. In one place where a road is cut through a sand dune, Eragrostis whitneyi var. caumii is growing well.

- b. Albatross runways. These were cleared in October, 1959. The parts which were not obliterated by the landing strip are now partially to completely covered with Boerhavia.
- c. Clearings around living quarters. Gnaphalium sandwicense is extremely abundant in areas where Cynodon dactylon has not been planted. Euphorbia glomerifera, Emilia javanica, Conyza bonariensis, and Eragrostis amabilis were found only here at the time the study was made.
- d. Clearing around radio tower. A series of cleared strips a few meters in width radiate out from the base of the tower to the guy-wire anchors. These strips cut through most of the eastern part of the central plain. Boerhavia diffusa, Lepidium o-waihiense, Lipochaeta integrifolia, and Solanum nigrum are moving into these areas.

It is too early to predict the total impact of the recently introduced plants on the indigenous species. However, if no further major construction occurs, most of the indigenous plant species are present in numbers large enough that they do not appear to be in immediate danger. There are two exceptions to this statement, Cenchrus agrimonioides var. laysanensis and Phyllostegia variabilis (if our plant proves to be this species). Cenchrus is no longer to be found on Laysan and has not been collected on Midway since 1902. The few plants remaining on Kure should receive some measure of protection. Phyllostegia is also extinct on Laysan and has not been collected on Midway since 1923. The Kure plant should be watched to verify the determination and should also be protected.

Photo: Green Island, Kure Atoll, view from southwest 1961, showing airstrip and installations.

Photo courtesy of U. S. Coast Guard.



II. Vascular plants of Tern Island, French Frigate Shoal

Through the courtesy of the United States Coast Guard and Dr. Harold F. Coolidge, the author was able to visit Tern Island on September 2, 1961. Since only half an hour ashore was available, during which time a circuit of the island was made, the observations reported here should be considered as "preliminary". I wish to express my appreciation to H. Ivan Rainwater who supplied me with a list of his collections from French Frigate Shoal, and to Dr. V. J. Krajina and Miss Marie Neal who assisted in the identification of the material designated here as Atriplex muel-leri.

French Frigate Shoal, about 480 miles northwest of Honolulu, is a crescent-shaped atoll on which are a number of sand islets. A few miles to the southwest are two rock islets, remnants of the original volcanic island. Tern Island, one of the sand islets (23° 54' N. Lat., 166° 19' W. Long.), is now the site of an airstrip and a United States Coast Guard loran station.

The botanical history of Tern Island is brief. The Tanager Expedition in 1923 (Christophersen and Caum, 1931) found five species of vascular plants growing there: Lepturus repens, Chenopodium sandwicheum, (now C. oahuense), Boerhavia diffusa, Portulaca lutea and Tribulus cistoides. During World War II the airstrip was constructed and some time later the loran station was built. H. Ivan Rainwater made plant collections on Tern and other islands in October, 1953. The second published observations were by Svihla (1957), who visited the island in 1956, and reported that the flora consisted of "various grasses", Ipomoea pes-caprae, Scaevola (probably S. sericea although no species was cited), and cultivated plants of Cocos nucifera and Casuarina sp.

Most of the surface of Tern Island is now occupied by the crushed coral airstrip which is 3100 feet long and drops off sharply into the water at the east and west ends. Along the south edge of the airstrip is an unpaved area 10 to 50 meters wide on which the living quarters are located. There is an extensive sandy beach along the south shore. On the north edge of the airstrip the unpaved area is up to 20 meters wide and there are only a few small sandy beach areas. The island is about two meters high. It is likely that little, if any, of the surface of the island was left untouched when the airstrip was constructed (see note p. 10).

The unpaved area south of the airstrip is rather densely covered with shrubs of Messerschmidia argentea and Pluchea odorata, and an herbaceous cover in which the predominant species are Ipomoea pes-caprae, Boerhavia diffusa, Cenchrus echinatus, Setaria verticillata, Sonchus oleraceus, and Conyza bonariensis. Of less frequent occurrence here are Eleusine indica, Lepturus repens, Portulaca lutea and P. oleracea. One large clump of Scaevola sericea is present southwest of the living quarters. Spergularia marina is abundant on the margins of the airstrip. The unpaved area on the north side of the island is less densely vegetated than that on the south. Pluchea odorata is present, but the shrubs are widely scattered. Very few plants of Messerschmidia argentea are present.

The herbaceous species are the same as those on the south except that Tribulus cistoides and Cynodon dactylon are also present on the north. Atriplex muelleri was found only in a single locality at the west end of the airstrip.

Cultivated plants around the Coast Guard quarters include Cocos nucifera, Casuarina equisetifolia, Ficus sp., Coccoloba uvifera, and Plumeria obtusa.

Of the five species noted by Christophersen and Caum (1931) for Tern Island all but Chenopodium oahuense were collected in 1961. The four species named by Svihla (1957) were still present. Fourteen additional species of weeds and cultivated plants are reported here for the first time. The flora now contains 22 species of vascular plants.

While it is impossible to determine the modes of introduction of the weedy species, it seems likely that the seeds of some of these came to the island in the soil which was reportedly brought there from Honolulu (Svihla, 1957). Honolulu was probably the place from which the cultivated plants were obtained. Other weedy species may have reached Tern Island accidentally via construction equipment, aircraft, or personnel. One cannot completely discount the possibility of "natural" dispersal by wind, birds, or ocean currents. However, most of the weedy species were present in the main Hawaiian Islands for many years before 1923, but the species were not found on French Frigate Shoal then. Thus, the weeds appeared there only after man began to make frequent visits.

The specimens cited below are deposited in the herbarium of the Bernice P. Bishop Museum, Honolulu 17, Hawaii. The initials "CHL" identify the author's collections made on September 2, 1961. The initials "HIR" indicate that the species was collected by H. Ivan Rainwater in October, 1953; "AS" indicates the species was collected by Arthur Svihla in February, 1956. The collections of Rainwater and Svihla were not numbered. New records are indicated by *.

GRAMINEAE

*Cenchrus echinatus L. CHL 1661.

*Cynodon dactylon (L.) Pers. CHL 1673.

*Eleusine indica (L.) Gaertn. CHL 1662, AS.

Lepturus repens (Forst.) R. Br. var repens. CHL 1668, 1674, HIR, AS.

*Setaria verticillata (L.) Beauv. CHL 1669, 1670, HIR, AS.

PALMAE

Cocos nucifera L. (Specimens not collected).

CASUARINACEAE

Casuarina equisetifolia L. CHL 1651.

MORACEAE

*Ficus sp. CHL 1659.

POLYGONACEAE

*Coccoloba uvifera (L.) Jacq. CHL 1660.

CHENOPODIACEAE

*Atriplex muelleri Benth. CHL 1654, HIR.

NYCTAGINACEAE

Boerhavia diffusa L. CHL 1671, 1675, HIR, AS.

PORTULACACEAE

Portulaca lutea Sol. CHL 1667, HIR.

*Portulaca oleracea L. CHL 1666.

CARYOPHYLLACEAE

*Spergularia marina (L.) Griseb. CHL 1663.

ZYGOPHYLLACEAE

Tribulus cistoides L. CHL 1652, HIR, AS.

CONVOLVULACEAE

Ipomoea pes-caprae (L.) Sw. CHL 1658, HIR.

APOCYNACEAE

*Plumeria obtusa L. CHL 1650.

BORAGINACEAE

*Messerschmidia argentea (L.f.) Johnston. CHL 1653, HIR.

GOODENIACEAE

Scaevola sericea Vahl. CHL 1656, HIR.

COMPOSITAE

*Conyza bonariensis (L.) Cronq. CHL 1655, 1665.

*Pluchea odorata (L.) Cass. CHL 1657, 1672, HIR, AS.

*Sonchus oleraceus L. CHL 1664, AS.

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Atoll Research Bulletin 51: 1-2, 1957.

Note -- The statement on p. 7, "It is likely that little, if any, of the surface of the island was left untouched when the airstrip was constructed," has recently been confirmed by Dr. Vernon E. Smith of Kaneohe, Hawaii. Dr. Smith tells me that he spent several days on Tern Island in 1940, at which time he did not observe any higher plants growing on the island.

ATOLL RESEARCH BULLETIN

No. 80

The tropical coral reef as a biotope

by

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Translated by Alan J. Kohn

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The tropical coral reef as a biotope

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On few marine habitats is there such a voluminous literature as on tropical coral reefs. However, most studies have been concerned with very well defined problems, primarily with the laws of growth of reefs and with theories which explain the origin of coral reefs and coral islands through the combination of biological and geological factors.

Only recently has there been concern with detailed studies of the living habits of coral polyps, of their nutrition, and of their dependence on different environmental conditions. Similarly, the various ecological zones of which the coral reef is composed have only been clearly defined in recent times and confirmed through faunistic studies. Here may be cited the works on fishes of a Pacific atoll by Harry (1953) and on the mollusks by Morrison (1954), works which confirm the validity of the reef zones distinguished by Tracey, Cloud and Emery (1955).

In contrast, for other groups of animals, the only statements at our disposal are those found scattered in the systematic and faunistic literature, together with the individual observations of various naturalists. No comprehensive summary seems to have been made as yet. Until recently, literally nothing was known about the microfauna of tropical coral reefs; indeed, it was not even known whether a microfauna could find the appropriate conditions essential for life in the environment of the coral reef.

I had the opportunity to study coral reefs in the Red Sea and the Maldive Archipelago (Indian Ocean) during the "Xarifa-Expedition 1957/1958."^{1/} Moreover the microfauna was the focus of the research; thirty samples from coral biotopes were collected in the Red Sea and 84 samples in the Maldives. The systematic study, by various specialists, of the assembled material has not yet been completed; therefore, a complete faunal list cannot be presented, and the following remarks must be considered as preliminary results, and they will have to be completed and enlarged after the conclusion of the systematic studies.

In the Maldive Archipelago the reefs and coral islands are always assembled in atolls and, like a string of pearls, enclose a lagoon 40-60 m. in depth. Channels cross the reef at many places and link the lagoon with the open sea. In addition, small reefs, which grow up from the lagoon floor without having any connection with the encircling reef, are found in many places.

^{1/} At this point I would like to thank Dr. Hans Hass, as whose guest I was able to work for seven months on the ship "Xarifa".

One must, therefore, distinguish between outer reef and lagoon reef. The outer reef is exposed to the breakers of the open ocean. A steep slope reaches up from the depths of the sea to a ledge, five to ten meters below the surface, which extends landwards as a reef terrace. Then the reef rises up to low tide level and there forms a characteristic zone under the influence of the heavy surf. Here calcareous algae of the group of Lithothamnion find especially favorable living conditions, coating the coral that grows there with a crimson red layer and also forming reef limestone themselves. From this Lithothamnion-zone a flat reef platform extends landward, situated just below low tide level and overgrown with small corals of various species, with alcyonarians, zoantharians and algae. Heliopora is also found here at low tide level.

The conditions described above were encountered on the reef of Hitadu Island, Addu Atoll, Maldives. In front of some other atoll islets, such a reef flat is lacking, but there is either a zone of sand stretching between the islet shore and the reef, or a zone of detached coral boulders.

A zone of sand separates the lagoon shore from the lagoon reef. The lagoon reef itself rises in pinnacles just to low tide level and is composed of many different species of corals. Here especially are found the branching, brittle forms.

Thus we can distinguish between different reef zones, which are characterized by different water depths and different influences from wave action. The analysis of the microfauna--as far as carried out--shows, however, only surprisingly insignificant variation between the individual reef zones: Exposed outer reef, protected lagoon reef, and the blocks of coral growing at depths of 10-30 m. exhibit a very closely similar fauna. Among the free-living nematodes a few species can be found which particularly prefer the flat coral biotope lying near low tide level, and it is likely that additional species with more specialized requirements will be found when the systematic study of the other groups is also completed, but the uniform character of the coral fauna is so striking, that individual differentiations can only play a subordinate role.

Such an ecological situation is in contrast with the conditions on sandy and soft sea bottoms, where both the force of the water movement and related with it the particle-size distribution and nature of the sediments, and the depth of water, have a great influence on the microfauna, so that one hardly expects to find any common species among the representatives of the microfaunas of an exposed beach and the sea bottom of a protected bay.

On the contrary, all of the coral zones investigated are inhabited by quite a uniform microfauna, and separation into particular biocoenoses does not appear justified, at least not now, because special character species which could identify the particular zones are lacking.

We shall now attempt to compare the microfauna of the coral heads with the fauna of other marine environments, since the considerable uniformity between coral fauna and "phytal fauna", the fauna which inhabits algae, hydroid colonies, and bryozoan colonies, is striking.

Thirty-six species of free-living marine nematodes were found on coral heads in the Red Sea (Gerlach, 1958). Of these, four species were new to science; most of the remainder had been collected previously by other authors in the Mediterranean Sea, Red Sea or Indian Ocean, and there among algae. The study of the nematode fauna of coral samples from the Maldives is leading to similar results, and Herr Dr. G. Hartmann (of Hamburg; oral communication), who is studying the ostracods of my collection, has come to the same conclusion.

On the lagoon reef of Welingandu Island, Rasdu Atoll, Maldives, I had the opportunity to make a series of 18 samples of the different species of corals occurring there, for their microfauna. This demonstrated again that the free-living marine nematode fauna shows no variation--is entirely the same--whether it inhabits branching corals such as Stylophora, Pocillopora and Psarmocora or massive, globular heads such as Porites, Favites, and Leptoria. Further, it also showed that the same nematode fauna occurs on corals which have died off and on which a crust of calcareous algae and other forms has developed. And finally, samples from Alcyonaria and the calcareous green alga Halimeda are not different from samples collected from living coral.

Only quantitative differences can be established, and these are closely related to the capacity of the coral polyps to secrete mucus. Upon irritation, the epidermis of the coral polyp secretes mucus, in which foreign objects fallen on the surface and small organisms become entangled; they are, together with the mucus, carried by ciliary movement to the edge of the coral head, and they fall to the bottom. There are corals, mainly those of the genus Acropora, which secrete mucus in great quantities. The sparsest microfauna is found on the heads of this species, and I have studied a series of Acropora samples usually without finding any associated fauna. In contrast, the richly populated corals such as Seriatopora, Pocillopora and Stylophora produce a distinctly smaller amount of mucus. Beyond this, whether this may also depend on the possibly different efficiency of the nematocysts of the corals is not yet known.

Therefore, I would characterize the nematode fauna, and probably the entire microfauna of coral heads as "phytal fauna" and include the coral reef among the "phytal" biocoenoses. The population density is great on dead corals which are overgrown with algae; in contrast, on living corals it is generally smaller. The coral reef thus represents an environment which apparently provides less favorable living conditions for the microfauna than does an abundant growth of red algae.

Of course, as stated above, the systematic work on the collected material is not yet completed, and it is possible that in the other animal groups of the microfauna, representatives will be found which are typical of the coral reef and do not occur in algal zones. An as yet unidentified aberrant copepod with a wormlike body, which apparently lives only on coral, mainly Pocillopora, certainly belongs here. These animals could be observed as they crawled about on the surface of the coral and slashed at the tissues of the polyps with the sharp claws of the first pair of legs. Here the point to be considered is that this is a form which has become particularly adapted to a mode of life

parasitic on coral. /Dr. Gerlach has kindly informed me in a letter that since publication of the original report, this form has been described by A. G. Humes (Kieler Meeresforsch., 16: 229-235, 1960) as a member of the new genus Xarifa of the new family Xarifiidae.--AJK/

No relations could be found with the fauna of the interstices of the sand. To be sure we found Ingolfiella litoralis Hansen, a slender isopod 2 mm in length, of which only a single specimen was previously known from coral from the Gulf of Siam. Ingolfiella ruffoi Siewing lives in coastal ground water, other species live in fresh ground water in the Balkan region, that means also in the interstices of the sand, but the conclusion that the representatives of the genus Ingolfiella could be considered as typical members of the interstitial fauna cannot yet be drawn, because one species, Ingolfiella bathybia Hansen, is known from soft sediments of the deep sea. The individual species of the genus therefore differ greatly with regard to ecology.

The macrofauna living on coral reefs in the Maldives may be divided into four groups according to the mode of feeding:

I. Suspension feeders are the group most abundant on living coral heads. Some of these animals, insofar as they feed on zooplankton, represent direct competition for food with the corals; others, mainly pelecypods and sponges, feed on phytoplankton and fine sestion, which are not utilized by the corals.

Specialized adaptations to the existing environmental conditions are found among the forms which prefer to occupy the living part of the coral head. Thus, here are found not only the true boring forms, such as the boring mussel, Lithodomus, but also bivalves, including oysters, gastropods (Leptoconchus, /Dr. Gerlach has kindly informed me in a letter that the original identification was in error and that the form has since been identified as Magilopsis lamarcki Deshayes by Dr. R. T. Abbott, Academy of Natural Sciences of Philadelphia.--AJK/ Vermetus), barnacles (Pyrgoma), and decapod crustacea (Hapalocarcinus, Cryptochirus), which allow themselves to be surrounded by the growing coral and thus gain protection from predators.

Sessile animals, which also occur in hard bottom communities, colonize the dead base of the coral head: alcyonarians (Lobophytum, Sinularia, Cespitularia), zoantharians (Palythoa), sponges, tunicates, and bryozoans.

II. Detritus feeders and small predators occur, but are not excessively abundant in comparison with their numbers in algal zones and benthic communities. Detritus occurs on the coral reef only in relatively small amounts. Where the bottom is not covered with coral, small areas of pure calcareous sand are found. The floor of the atoll lagoon, under 30-40 m of water, is covered with calcareous sand which is also comparatively poor in organic debris. Only on the dead bases of the corals is there an algal growth worthy of mention as a food source for the microfauna. Representatives of the microfauna are mainly copepods, amphipods, isopods, tanaidaceans, ostracods, polychaetes, and nematodes.

To the group of detritus feeders and small predators belong a few brachyuran crabs and a few shrimps, which regularly live among the branches of the branching corals. Grazing gastropods are not common. An as yet unidentified holothurian sweeps with its tentacles the surface of all the dead coral heads. Serpent stars also occur regularly and are to be placed in this group of detritus feeders and small predators.

A number of coral fishes seek their food among the coral heads. Some are specialists, with elongate, pincer-like snouts, such as, according to the identifications by Herr Dr. Klausewitz (of Frankfurt), Forcipiger, Gomphosus, and Oxymonacanthus, and in addition many chaetodontids, acanthurids, and pomacentrids. Living directly in the coral heads are small fishes of the genera Gobiodon and Caracanthus. Chromis and Dascyllus, in contrast, use the branched corals as habitat and refuge, but seek their food in the plankton above the coral heads.

III. Predators have the smallest food sources on the coral heads and correspondingly are not abundant. Among the crustaceans, stomatopods and alpheidids may be listed here, as well as predatory gastropods, polychaetes, and sea stars.

Whether nudibranchs and pycnogonids feed directly on the tissues of the coral polyps has not yet been determined. This could be observed in the case of one aberrant copepod /Xarifa/.

IV. Finally, fishes of the genus Kyphosus and above all parrot fishes (Scaridae) must be mentioned as the last group. With their strong jaws they bite off entire pieces of coral colonies and swallow with them the fauna living on them.

If we now ask which animals of the macrofauna stand in close ecological relation with the living coral reef as environment, an obvious case is that of the parrot fishes, which feed on pieces of coral, and that of those suspension feeders which let themselves become enclosed by the coral. To what extent the numerous "coral fishes" are adapted to the particular environmental conditions of the reef, or whether they also occur in comparable places where coral does not form the biotope, still remains open. The crabs of the genus Trapezia appear to prefer the coral biotope; whether this also is true of the other invertebrates found on the reef remains to be tested.

The aim of this investigation was to determine the place of the tropical coral reefs in the framework of marine environments. The opinion of Stephenson (1958) that the coral reef corresponds to the sublittoral algal region in the temperate zone was confirmed. The investigation of the microfauna shows especially that the coral reef can be included among the "phytal" environments. The common elements in the fauna of the coral reef and in algal regions are many, by contrast the forms especially adapted to life in close relation with corals are few, and it would not be quite justified to contrast at the same level the coral reef with the benthic and phytal biotopes.

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ATOLL RESEARCH BULLETIN

No. 81

Qualitative description of the coral atoll ecosystem

by

F. R. Fosberg

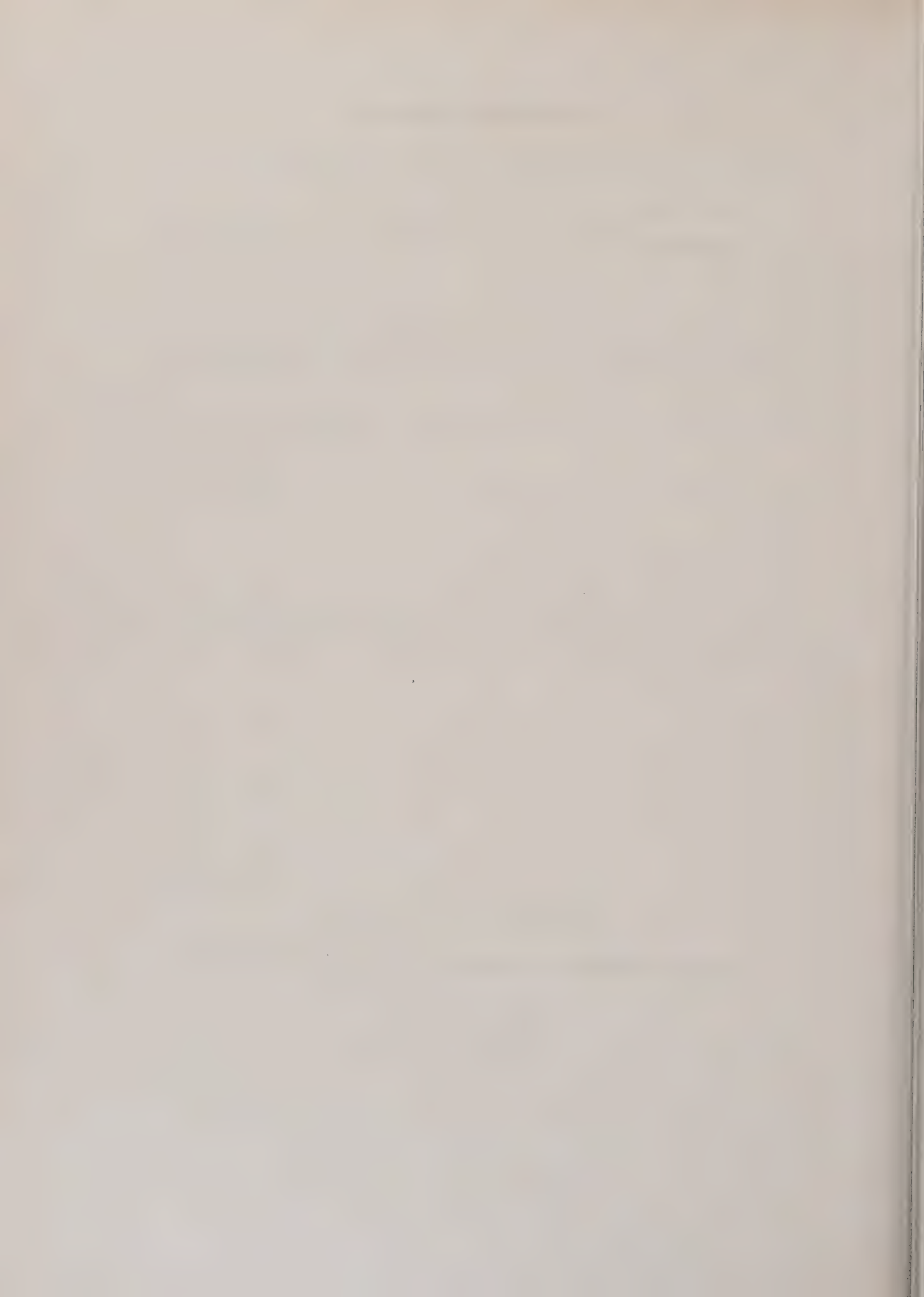
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Qualitative Description of the Coral Atoll Ecosystem*

by F. R. Fosberg

A coral atoll may be described, in the briefest terms, as a cap of limestone of organic origin on a mountain on the floor of the ocean, rising to or only slightly above sea level. Some lie on shallow banks or continental shelves. The cap is commonly bowl-shaped on top with a ring-like ridge or reef surrounding a body of water termed a lagoon. Some parts of this reef may emerge above high tide level as islets. These may either be remnants of former higher reef levels or detrital accumulations. Much or all of the reef surface below mean low-tide level and down to depths where sun-light penetration is very attenuated is composed of communities of living plants and animals. In bulk, at least, these are mostly organisms that secrete limy skeletons. Accumulations of these skeletons make up, almost exclusively, the reefs and upper parts of the mountain down to the volcanic (or other) basement rock on which the reefs originally started to grow. The depth of this limestone is known for only a few atolls and may vary from at least 1400 meters to, probably, very much less.

The concept of the ecosystem, first proposed by Tansley (1935), is that of an interacting system composed of an environment and all of the organisms involved with it. It is normally an open system because there is a continuous, though variable, influx and loss of energy and material. Such a system is, of course, an abstraction constructed to facilitate understanding of the complex processes involved in a segment or class of segments of the biosphere. As such its extent is limited only by selection and definition of the segment or segments under study. Thus it may be varied, in different examples, from the smallest observable unit of environment in which organisms live to the entire world's biosphere as a whole with its total environment (Evans, 1956). As the ecosystem is only limited by the extent of the effective environment the maximum could be, theoretically, the entire universe. Practically, however, the definition will not ordinarily extend to the ultimate sources of energy, or even of material. It will be restricted to such extent as will best facilitate observation and understanding of the portion of nature under immediate study. This concept, of obvious and increasing utility but not too easy to handle, and never, apparently, used by its creator, has been, in recent years, adopted by a number of ecologists (e.g. Pitelka, 1955; Billings and Bliss, 1955; Oosting, 1956; Evans, 1956; Cain, 1956; Dansereau, 1957). No two have defined or formulated their ecosystems in exactly similar terms, nor is there any critical need, at this stage, to do so.

In this paper the coral atoll ecosystem will be described in terms of processes involving transfer or transformation of energy and material, with only incidental reference to the actual organisms involved in the system or to the physical structures found in the environment. It is

* Presented as a part of a symposium on Algal Ecology, with Special Reference to Coral Reefs and Atolls, at the 9th Pacific Science Congress, Bangkok, Nov. 21, 1957.

recognized that in a complete account of such a system these aspects, also, would be described fully. For present purposes it may suffice to say that the biotic component of the system is composed of phytoplankton and zooplankton; free-living but bottom-dwelling animals and other heterotrophic organisms of many sorts; an enormous aggregation of sessile or fixed organisms representing most classes of algae, a few seed plants, and practically all phyla of invertebrate animals; and a diverse assortment of land animals and plants. Many of the marine organisms secrete skeletons of CaCO_3 which are added to the material of the substratum. This process forms a lattice-work of limestone in which free skeletons or loose fragments lodge. By several processes these may become bonded in such a way as to form a rather hard and resistant rock. This is built up in the form of a ridge or reef usually enclosing a shallow body of water or lagoon and rising variously to somewhat below, near, or just above high-tide level. This reef is ordinarily rather flat-topped, of varying width, with irregularities or islets extending above high-tide level. Waves commonly break on the outer margin and water flows from the sea to the lagoon and back to the sea over the flat or gently sloping reef surface or through gaps in it. The flow may be in and out with the tides, or in over the windward and out over the leeward sides. The islets are commonly composed in part or wholly of loose porous limestone debris and are mostly covered by vegetation that includes representatives of all major groups of land plants. The land faunas are made up of a large number of species of insects and other arthropods, worms, land molluscs, a few reptiles, some birds, and a few mammals, including rats and man. Larger islets may contain within their porous structures a body of fresh ground water floating on the underlying salt water and retarded by friction from free diffusion with it.

These atoll structures are found in most regions of the tropical and, more rarely, subtropical seas. Temperatures range generally between 75° and 85° F. or in full sun on land, higher, decreasing of course with increasing depth in the sea. General climates range from relatively dry, perhaps 600 mm. precipitation, to wet, 5000 mm. or more. The atolls are in trade wind, doldrum, and monsoon belts. Insolation is generally high, cloudiness low to moderate.

Most atolls are inhabited by human beings, some by relatively large populations. These exert a generally appreciable, often profound, influence on the functioning of the ecosystem. Of specific importance in this connection are the economic activities of planting coconuts, harvesting, drying, and exporting coconut meat, and importing in exchange various foods and other materials.

With this description of the general physical and biological situation, we may proceed to describe in more formal terms, the abstraction called the coral atoll ecosystem. This may be outlined as follows in 12 sections, lettered A to L.

A. Media.

B. Nourishment or inflow.

C. Production.

- D. Transformation.
- E. Decomposition.
- F. Excretion.
- G. Accumulation.
- H. Turnover.
- I. Miscellaneous other effects and processes.
- J. Losses.
- K. Balance.
- L. Trends.

A. Media: The media in which the system exists are two--a layer of sea water and a superimposed layer of air. These, by the nature of the earth-system itself, are constantly changed by sea and air circulation. Through them, or by means of them, all exchange, gain and loss, of matter and energy takes place. These two media are the most universal and pervasive components of the ecosystem and at the same time its environment, influencing in some measure everything in the system.

B. Nourishment or inflow: Since the atoll is an open system there is a continuous addition of matter and energy in many forms. Fundamental, of course, is the daily increment of solar energy without which the system, in anything like its present form, could not exist. Its functioning is in almost every respect dependent on either photosynthetic or thermodynamic processes, which are dependent on constant addition of energy from the sun. The nourishment of organisms and the circulation of both air and water are important examples.

The energy of wind, mostly indirectly a form of solar energy, also exerts its force in various ways in the system. Most of this energy is received elsewhere and transported to the atoll.

The gravitational energy of both sun and moon contributes importantly to sea-water circulation in the form of tides. The movement of ground water in atoll islets also is influenced by tidal fluctuation.

Essential components of the media, such as O_2 , N_2 , H_2O , CO_2 , as well as dissolved salts and suspended organic matter, and even living propagules and disseminules of organisms are continually renewed or carried into the system by air and ocean currents. Relative concentrations of the various components of the media are maintained at a rather constant level in this manner. The replenishment of the ground-water bodies in islets is dependent on incoming fresh water, mostly evaporated elsewhere and deposited as rain on the islets from wind-borne clouds. Surface currents, upwellings, trade-winds, monsoons and cyclonic storms are important aspects of the circulation patterns involved. The introduction into the system of phosphorus, on which organic activity is completely

dependent, is believed to be controlled to a considerable extent by upwellings of deep-sea water. One important route of transport of phosphorus from areas of upwelling to the atolls is by means of fish-eating birds and their young which deposit phosphates in their excreta within the area of the system. Essential mineral elements, nitrogen, and organic carbon are also brought in by the birds at the same time. Organic matter, in the form of drifting plankton, driftwood, and dead organisms, is brought to the atolls by currents. Currents also bring small amounts of mineral elements in the form of pumice as well as in solution. Volcanic ash arrives by way of winds, especially high altitude winds.

Finally, with changing patterns of human activity on atolls, increasing amounts of imported foods and other materials as well as alien organisms are introduced into the system. These introductions are effecting various rather profound changes in the equilibria and altering greatly the physical appearance of the atolls.

C. Production: The elaboration by plants of basic organic materials from elements and simple inorganic compounds is termed production, in an ecological sense. Such elaboration provides the fuel and building materials for all other life processes. The effective capacity of a system for production is called its productivity.

(1) The most obvious productive process is photosynthesis, by which carbohydrates are elaborated. Algae and green plants utilize CO_2 , H_2O , and energy from sunlight for this purpose. Such algae occur as components of plankton, within the cells of corals and other coelenterates, fixed on the reef surfaces, terrestrially on soil and rocks, and epiphytically on tree trunks. Mosses are found in many terrestrial situations on the islets, as well as on tree trunks, especially where they are shaded. Ferns and psilopsids are common growing on land and epiphytic on trees. Seed plants grow principally on land, but some are epiphytic and a few are marine, growing in shallow lagoon situations on sandy bottoms. All of these groups, together, account for the origin of most of the carbohydrates used in the system.

(2) The other essential type of production is the fixation of atmospheric nitrogen--its oxidation and elaboration into simple compounds. It is well known that this fixation is accomplished by bacteria in the soil and in nodules on the roots of certain leguminous plants. Less well known, but possibly more important in the atoll system, is fixation of nitrogen by blue-green algae. This occurs on the soil surface and possibly in fresh and salt water. Much of the nitrogen available to atoll organisms is probably fixed within the system, but important quantities enter the system by way of birds, rain, and ocean currents.

D. Transformation: The alteration of primary and fabrication of secondary organic compounds: This function may be viewed as a succession of processes, mostly involving a break-down of organic compounds and their re-elaboration into more complex ones. Some of these are of an enormous order of complexity (e.g. nucleo-proteins).

(1) Autotrophic plants, in the nourishment of their own protoplasm and elaboration of stored material, cellulose, lignin and other materials,

carry out the first major step in a series of turnovers of the products of photosynthesis. Of course, additional inorganic materials are incorporated by this process and many of the elaborated compounds are infinitely more complex than the original carbohydrates produced by photosynthesis.

(2) Heterotrophic (parasitic and saprophytic) plants carry this process a step farther in utilizing already elaborated complex substances, as well as simpler materials derived from their hosts and organic substrata. Here may be mentioned the utilization of dissolved organic matter in the media by facultatively heterotrophic planktonic algae as discussed by Saunders (1957).

(3) Animals, feeding on plants in various ways, convert plant organic matter into animal organic matter. The principal classes of processes by which this is accomplished are as follows:

- a. Eating of phytoplankton by zooplankton.
- b. Utilization of material produced by zooxanthellae, by their coelenterate hosts.
- c. Reef grazing and boring.
- d. Eating of land plants by animals.
- e. Eating of dead plant parts by animals.
- f. Parasitism of plants by animals.

(4) Secondary conversion of animal matter to animal matter is accomplished as a result of three well-known classes of processes, namely:

- a. Predation.
- b. Parasitism.
- c. Scavenging.

These are carried on in a great number of different ways by a large number of animals. Reef grazing and boring are important here, too.

(5) Reconversion of animal matter to plant matter is not as conspicuous a process, but is important nevertheless. There seem to be no insectivorous plants on atolls, so this reconversion is principally accomplished by bacteria and fungi living mostly on dead, and occasionally on living organic matter. It is an interesting question whether zooxanthellae utilize in any way the materials of their hosts' tissues.

E. Decomposition (usually but unfortunately termed "reduction"): The destruction of the elaborated organic compounds and reconversion back to simple inorganic compounds and relatively inert organic residues: Two main categories of processes are involved here.

(1) Physiological oxidation (inappropriately termed respiration by many plant physiologists), which is the oxidation of carbohydrate materials within living cells releasing the energy required for other life processes. This process goes on constantly in all living things.

(2) Non-biological oxidation, both by burning and by the slow oxidation of dead materials that normally takes place on exposure to atmospheric oxygen, aided or not by hydrolytic and catalytic action.

The principal products of both sorts of processes are CO_2 and H_2O , with, of course, inorganic and inert organic residues. Chemical energy is released and converted into other forms.

F. Excretion (within the system): The release of waste products and residues by organisms into the media:

(1) In water CO_2 and O_2 are released, as well as excreta and soluble metabolic wastes. Calcareous and siliceous skeletons and oily material remain after disintegration of organisms.

(2) On land, likewise, CO_2 , H_2O , O_2 , and metabolic wastes are released in solution in air or water. Guano and other excreta, as well as dead bodies and deciduous, caducous, or severed plant parts are deposited on the surface of the ground to decompose.

G. Accumulation: Storage of materials in unchanging or very slowly changing form, i.e. temporary withdrawal of material (and energy) from free circulation in the system. .

(1) In bulk the limestone from calcareous skeletons of plants and animals represents the greatest and most important accumulation, the principal component of the atoll itself.

(2) Phosphatic residues, mainly calcium phosphates, are present as phosphate rock, components of soils, guano, and at least in some atolls (e.g. Washington Island) as a phosphatic mud or sludge on the lagoon bottom.

(3) Humus, both as raw humus in *Pisonia* forests, and as more stable humic residues in A_1 horizons of soils, plays an important part in the functioning of the system. The acid raw humus contributes to the formation of phosphate rock, and the soil humus helps to maintain the soil in condition to support growth of larger plants and micro-organisms. Humus, though relatively inert, is continually undergoing a slow oxidation.

(4) Slight accumulations of charcoal, metal oxides, silica and silicates occur where human activity is significant. Silica from sponge, radiolarian, and diatom skeletons also occurs in minute amounts as well as small quantities of silicates from floating pumice.

(5) Finally, fresh water, in the ground-water lens, as well as in the several states of soil water, may be regarded as a temporary accumulation.

The organic matter and other substances in living organisms represent a large total quantity but, as they are in a constant state of turnover, should probably not be classed as an accumulation.

These accumulations, along with the materials in solution in the media, may be regarded as the reservoirs of materials on which the other components may draw for nourishment.

H. Turnover of materials and energy: Categories D, E, and F, above are to be classed as turnover. In addition several more processes may be so regarded.

- (1) Re-use of CO_2 released by oxidation.
- (2) Re-use of O_2 released by photosynthesis.
- (3) Re-use of H_2O released by metabolic and external chemical processes.
- (4) Re-use of fixed nitrogen, both from metabolic wastes and from primary biological oxidation.
- (5) Re-use of mineral nutrients released by excretion and breakdown of organic materials.
- (6) Withdrawal from and return of various materials to media.
- (7) Withdrawal from and return to accumulations.

I. Miscellaneous other effects and processes taking place within the system.

(1) Inhibition by salt (NaCl). The organic activity in terrestrial situations seems subject to a considerable inhibition by the salinity of the sea-water medium. This inhibition results from difference in osmotic pressure, the chemical effects of absorption of excess sodium and chlorine ions and consequent inhibition of absorption of others. The number of land organisms completely adapted to the normal salt concentration of the sea is limited. Hence establishment of immigrant organisms is severely limited, and many of those that become established function at below their optimum levels. Salt water enters the land environment as wind-borne spray, as storm waves, and by diffusion through the ground. The conspicuous nature of the limiting effects of salinity may be a reflection either of the small extent of the land habitat and consequently great exposure to salt or of its probable geologically recent origin that has allowed little time as yet for evolution of a special atoll biota.

(2) Effects of sea-air interface: Category 1 is really only one of the consequences of the fact that the land portion of this ecosystem is a thin lens inserted in the general sea-air interface. The distribution of many organisms, marine as well as land, is influenced by the character of this interface. Aeration, principal release of energy from insolation, frequently an abrupt break in temperature gradient, local high salt concentrations resulting from evaporation, solution and other forms of

erosion of limestone, and the shaping of the contours of vegetation and control of its composition are all consequences of the nature of this interface. Many more could be enumerated.

(3) Shelter effects. One of the reasons for the diversity of animal life in such an apparently simple environmental complex may be the variety of habitats resulting from the surface irregularity of the several substrata. The vegetation, the deeply pitted rock, the porous soil, and the intricate nature of the reef lattice provide shelter of various types for a large number of species of animals (and plants, too) that have widely differing requirements.

(4) Burrowing and turning over of soil by crabs is an important factor in the process of incorporating organic matter into the soil. Crab burrows are very common on many atolls, and fresh mineral soil is often piled or scattered around their entrances. The mechanical tilling of the soil in this manner has been compared to that accomplished by earthworms in other habitats. It doubtless is a process of great importance, though no careful assessment of its extent or effects has been made.

J. Losses (or excretion from the system):

a. Of the principal substances lost from the system the first three listed below are present in such constant proportions in the media outside the ecosystem that the losses may be considered as balanced almost exactly by inflow. The others are fluctuating quantities and there is no exact relation between inflow and loss.

- (1) CO_2 carried away by winds and currents.
- (2) O_2 , carried away by winds and currents.
- (3) N_2 , carried away by winds and currents.
- (4) Fresh water dispersed into media and carried away by winds and currents.
- (5) Nitrates and organic N, carried away by currents.
- (6) Phosphates, carried away by currents in solution and suspension.
- (7) Other dissolved mineral substances, carried away by currents.
- (8) CaCO_3 carried away by currents in solution and suspension.
- (9) Plankton carried away by currents.
- (10) Dead animals and plants and detached living fixed organisms carried away by currents and storms.
- (11) Birds and other organisms which migrate.
- (12) Export of copra.
- (13) Export of pearl shell, etc.

b. Energy losses:

- (1) Light, by reflection.
- (2) Heat, by radiation and convection and carried by winds and currents.
- (3) Chemical energy lost with elaborated materials.

K. Balance: The resultant of all of the factors at work on the segment of the universe (or of nature) occupied by the atoll ecosystem is the atoll itself. It may be thought of as a system in a state of dynamic equilibrium with a positive offset represented by the physical mass of the atoll with its associated biota, the total accumulation of organic and mineral matter over and above that of the normal media--air and seawater--that otherwise would occupy the space. All the characteristics described serve to set the system off from the surrounding undifferentiated media.

L. Trends: With such complexity it is hard to estimate trends, though it may be easy to discern them. Over very long periods the trend is obviously toward greater accumulation of material and probably toward increasing complexity. This trend usually seems directly related to slow subsidence of substratum on which the atoll is built, and may be expected to continue. On a shorter time scale it is possible to suggest that during periods of general or eustatic rise in sea level mass will increase, by addition of calcareous material in layers. Biotic complexity may at the same time decrease somewhat with tendency toward loss of land habitats. With fall in sea level the trends may be the opposite--loss of mass by erosion and gain in biota with appearance of land habitats, increased activity of sea birds, and especially the results of occupation by man. Presumably for about the last 3500 years the latter trend has been generally maintained. Whether or not the last few decades have witnessed a change in this trend is uncertain.

It seems clear that these major trends and fluctuations are controlled by factors external to the system. The ultimate control of sea level is as yet by no means clear. The variation in CO₂ content of the air has been suggested (Plass, 1956) as a factor that determines, or at least influences, world temperatures, evaporation of sea water, accumulation of ice, and consequent effects on sea level. It has been suggested that the recent apparent reversal of the fall of sea level may be due to the vastly accelerated industrial activity which pours great quantities of CO₂ into the atmosphere. If this is a valid assumption it seems reasonable to think that the present rise will continue, probably at an increasing rate. Thus a prediction might be made that the presently observed loss of land above water by erosion may be accelerated by a rise in sea level and consequent submergence of much or all of the land area of atolls. Such predictions, however, rest on very insecure bases at present.

On a still shorter time scale are the effects produced by the occupancy of the atolls by man, and especially modern man. These effects tend to be drastic as far as the land portions of the ecosystem are concerned but trends are as yet hard to isolate. Certainly the replacement

of the native vegetation by coconut plantations and the rise of the export of copra are notable and probably involve a complex of related or dependent effects. This change will probably continue but certainly at a decelerated rate, as land for expansion of plantations is becoming scarce. Augmentation of the land biota will probably continue as man's effect on the land environment continues. Pollution of lagoons will undoubtedly increase, with resulting encouragement to some organisms and ill effects on others. Fishing activities have tended to decrease with contact with civilization but this trend may probably be reversed and with use of such effective methods as dynamiting and poisoning the marine biotas may undergo considerable change. There has as yet been little attempt to measure the results of such factors so that here, as in other aspects of the system, estimation of trends is highly speculative. If such prediction is of interest, attention should be directed toward critical study of the details of the working of the system outlined above, to clarify it and fill in the parts that are at present inferential. It seems possible that if a firm understanding of this ecosystem is achieved it may be used as a model in terms of which to study other ecosystems.

Summary

The general physical and "physiological" framework of the coral atoll ecosystem has been outlined in terms of the media in which the system exists, nine categories of processes taking place within the system, the balance or dynamic equilibrium in the resultant structure brought about by these processes, and suggested trends in the state of this equilibrium. This highly generalized picture rests on a vast accumulation of facts and upon inferences drawn from them and from pertinent facts derived from study of related or analogous situations in other systems. It is hoped that this description may serve, until a better conception is devised, as a framework around which an understanding of this segment of nature may be built and as a guide for future research designed to clarify our knowledge and appreciation of coral atolls.

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ATOLL RESEARCH BULLETIN

No. 82

Heron Island, Capricorn Group, Australia

- I. Description of Heron Island, by F. R. Fosberg
- II. Vascular plants of Heron Island, by F. R. Fosberg and R. F. Thorne
- III. Some observations on the Heron Island fauna, by J. M. Moulton

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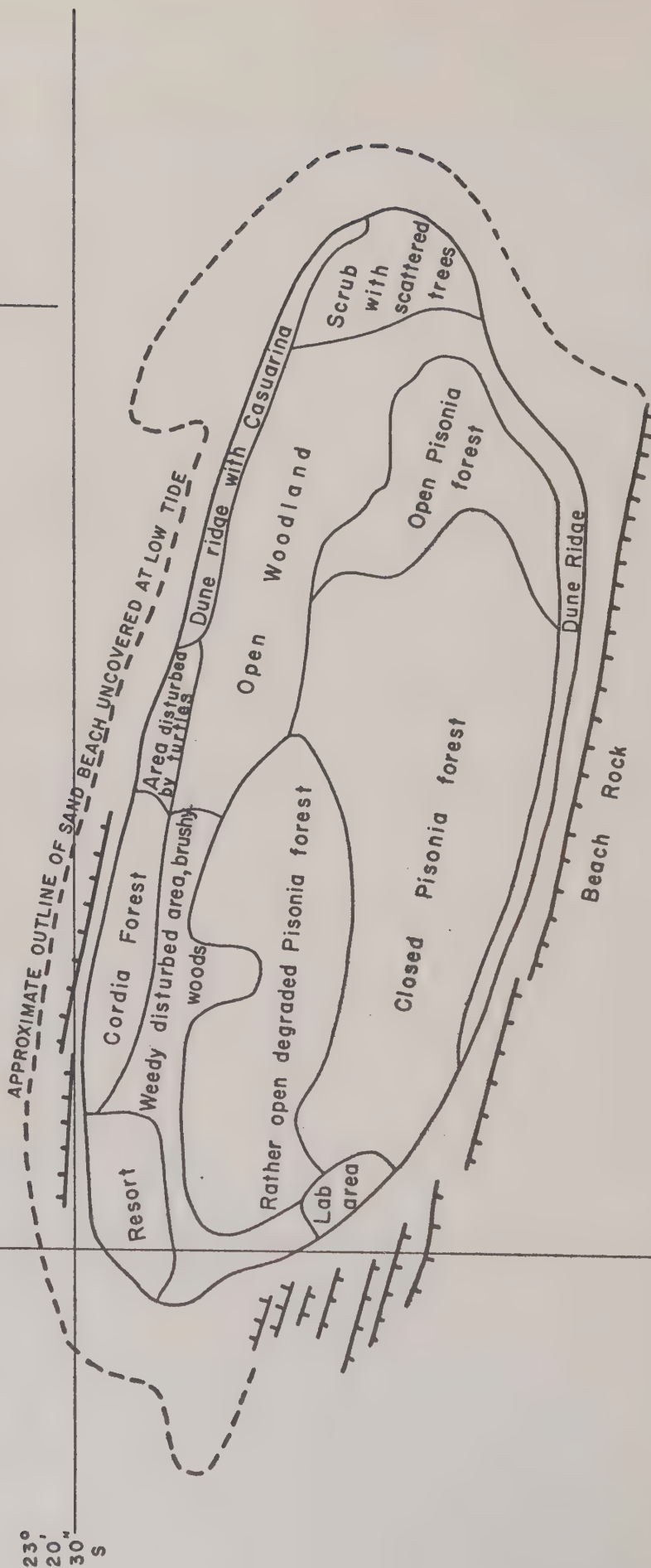
Washington, D. C.

December 31, 1961

151° 55' E

SKETCH MAP OF HERON ISLAND CAPRICORN GROUP QUEENSLAND, SHOWING DISTRIBUTION OF VEGETATION

0 100 METERS
APPROX. SCALE



23°
20'
30" S

are a few slender trees of Celtis paniculata, and, forming a very sparse lower story, shrubs of this species, Ficus opposita, and Pipturus argenteus which are 2 to 4 m. tall. A shrub or tall herb layer, locally quite prominent and almost continuous, is formed of Abutilon albescens and, in places, Euphorbia cyathophora. In open places is a mat of Wedelia biflora a meter or so thick. Where the Pisonia is thickest this shrub layer is sparse or lacking. Low herbs are almost lacking except for small patches of Stenotaphrum micranthum. At this time (October 1960), after a long dry spell, the Pisonia is largely leafless, especially the upper branches, and is just coming into flower. This relatively dense Pisonia forest occupies the central and western parts of the island, except for the south dune ridge and a strip along the north coast. It has been disturbed on the northwest corner by the building of the resort, and on the southwest by the building of the Marine Biological Laboratory and caretaker's house. Around the resort buildings as a precaution against storm damage, the upper branches of the Pisonia have been lopped off. Occasional fallen Pisonia trees are observed in the forest, mostly producing sprouts from their trunks.

East of the middle of the island, especially near the south side, the Pisonia forest is much more open. Here Celtis and Ficus are more common and larger, Pandanus is occasional, and the undergrowth of Abutilon and Wedelia is prominent, with occasional patches of Euphorbia cyathophora.

Along the north side, beginning at the resort, the forest, for a little distance in from the beach, is dominated by Cordia subcordata, rare or absent elsewhere on the island, with some Pisonia. This forest is not especially dense and has an undergrowth, in the spaces between the low-branching crowns of the Cordia, of Abutilon, Wedelia, and Euphorbia. Scaevola and Tournefortia are common in the edges along the beach, with a loose sod of Sporobolus virginicus at the top of the beach. Along the dune ridge on the south side is an irregular scrub forest of Pandanus, Casuarina, Tournefortia, and Scaevola. On the steep sand slopes above the beach Euphorbia ramosissima, Cakile, and Thuarea are common.

East of the Cordia forest is an area of open sand, much dug up by turtles, with scattered small Casuarina, Ficus, Scaevola, Pandanus, and Tournefortia. On the sand are Cakile, Wedelia, Lepturus (mostly dead at this season), Euphorbia eremophila, and Cassytha; the latter is parasitic on many of the other plants.

Eastward, and also east of the open Pisonia forest, the undergrowth becomes thicker and Pandanus becomes dominant in the tree layer. Celtis, Casuarina, Ficus, some Tournefortia and several dense patches of Suriana are also present. Scaevola and Wedelia are common, as well as Abutilon. A dead grass, probably Lepturus, and Euphorbia eremophila are common and Cassytha is very prominent, thinly covering the bushes and, locally, the ground.

At the east end is an irregular scrub 1 to 2 m. high, of Tournefortia and Scaevola, open in places, and with irregularly scattered small Casuarina trees. These trees are especially notable at the top of the beach and extend in a line on the low dunes along about half the north coast, and along the dune ridge on the south coast.

I. Description of Heron Island

by

F. R. Fosberg

Heron Island, of the Capricorn Group, at the south end of the Great Barrier Reef, Queensland, Australia, is the site of the Marine Laboratory of the Great Barrier Reef Committee and also of a small resort. It is reached by a 4 to 5 hour launch ride from the port of Gladstone, Queensland.

J. B. Jukes (Narrative of the Surveying Voyage of H.M.S. Fly ... 1:6-9, 1847) gave a rather general account of the island, but paid particular attention to the beach rock, which he described in detail, with one of the earliest scientific speculations as to the origin of beach rock.

Heron Island is a small island, narrowly oblong or bullet shaped, about 45 acres in extent, formerly more than 100 acres, but said to have been largely swept away by a hurricane; it lies on the western end of an elongate reef, 5 miles long. This reef is separated from Wistari Reef by a narrow channel. It lies just inside the tropic of Capricorn at lat. 23°26' 30" S, long. 151°55' E.

The entire island is a sheet of flat coral sand mostly one to two meters above high tide level. The highest point (near the guest house) is 3.6 meters above high water (H. F. Manning, conversation, 1960). Along the south side is a dune ridge rising to perhaps 3 meters at most, above the general level of the island. Along the north side, at least in the eastern part, is a much lower dune ridge, at most a meter above the general level of the island. On the northeast corner is a notable sand apron on the reef below the beach.

A broad series of inclined beds of beachrock extends along the entire south coast, leaving the coast where the beach swings north and shortly disappearing. On the north coast a narrower strip starts at the curve in the west end and extends a short distance along the beach. Then, slightly offset to seaward, a very narrow, much eroded and pitted strip extends perhaps nearly half the length of the island. On the south side large numbers of slabs of beachrock have been torn loose and strewn along the upper part of the beach. These beds are said to be completely buried in sand at times. Toward shore, at the extreme west end, the beds on the south side become horizontal or even dip slightly toward shore. It is hard to tell whether these are normally exposed beds or have been laid bare by stripping off the upper beds for use as building stone for sea walls around the resort, as this activity was taking place during my visit. There is no other consolidated rock of any sort on the island.

The most notable vegetation type on the island is a low forest of Pisonia grandis, of trees perhaps 6 to 8, rarely 10 m. high. The pale gray or cream-colored elephantine trunks of this tree give a character to the landscape that is not easily forgotten. Scattered in this forest

The vegetation of the island has a considerably disturbed look. Trails and roads have been cut into the Pisonia forest, and around the resort and the laboratory weeds are very abundant, especially Euphorbia cyathophora and Gnaphalium sp. Exotic plants have been set out in some abundance, but except for one small coconut tree, a few papayas, an oleander and one or two plumerias, most of them are still small.

Much of the appearance of disturbance comes from the burrowing of the wedge-tailed shearwaters or mutton-birds (Puffinus pacificus) which stir up the ground on most parts of the interior, and from the holes dug by green turtles (Chelonia mydas) and occasional loggerheads Thalassochelys caretta, which lay their eggs here, the former in great numbers. The ground around the margins of the eastern half of the island appears thoroughly churned up by their activities.

Before this visit I confidently anticipated finding phosphatic hardpan soils, with raw humus accumulation, of the Jemo series,* similar to those found in the Central Pacific atolls. The conditions, as described, with Pisonia forest growing on coral sand, with abundant seabirds, seemed perfect for development of soils of this series. Actually, no phosphatic hardpan whatever was found, and only a very small patch showed any raw humus accumulation. This little area was, apparently by chance, not disturbed by shearwater burrows.

The absence of either phosphatic hardpan or an extensive raw humus layer was anticipated by Dr. W. Stephenson, of Brisbane University Zoology Department, in a conversation before the visit. He said that the constant stirring up of the soil by the shearwaters and mixing in of coral sand with the humus would probably prevent much accumulation of humus, and consequently, no phosphate rock formation could take place granting the correctness of my theory* on the process. His prediction was realized. The absence of phosphate rock in this area, where neutralization of the humic acidity by calcium carbonate sand is the rule, may possibly be regarded as further evidence for the soundness of the theory.

Nearby Mast Head Island is described (by H. F. Manning, conversation 1960) as having thick Pisonia forest also, but with abundant nesting of crested terns (Thalasseus bergii), the burrowing shearwaters being present but not predominating as at Heron Island (see Barrett, C., Nat. Geogr. Mag. 58: 354-384, 1930, who reports shearwaters there). It is suggested that a well-developed layer of raw humus overlying a bed of phosphatic hardpan will be found there. Phosphate has been exploited on Lady Elliot Island, 60 miles to the southeast of Heron Island, but no information is readily available as to its nature and origin.

J. B. Jukes (Narrative of the Surveying Voyage of H.M.S. Fly 1: 2, 1847), in his account of "First Bunker's Island", described what must certainly be Jemo soil as follows, "The materials of the encircling ridge were quite low, and thinly covered with vegetable soil among the trees; but the sand of the central plain, which was dark brown, was sufficiently

* Fosberg, F. R., Soil Science, 78 : 99-107, 1954.

compact to be taken up in lumps, and a little underneath the surface it formed a kind of soft stone, with embedded fragments of coral. Some vegetable soil also was found, a few inches in thickness in some places, the result of the decomposition of vegetable matter and birds' dung." Saville-Kent, in *The Great Barrier Reef of Australia*... 101-102 [1893], quoted Jukes' description of First Bunker's Island and assumed that it applied to Lady Elliott Island. However, Jukes (op. cit. opposite p. 3) illustrated Lady Elliott Island, referring to it by that name. From the location, as described in Jukes narrative, it seems more likely that First Bunker's Island was Lady Musgrave Island, a few miles to the north of Lady Elliott.

II. Vascular plants of Heron Island

by

F. R. Fosberg and R. F. Thorne

Through the courtesy of the Great Barrier Reef Committee, the authors were able to make collections of the vascular plants of Heron Island. These collections, made at different seasons, May and October, complement each other and it seems proper to make a combined report of them, and to include several records from the herbaria at Brisbane and Sydney. No systematic search for such records could be made, because of lack of time. Also added are sight records of species planted, mostly in pots, at the resort on the island.

A previous list, by W. D. K. MacGillivray and F. A. Rodway, based on collections made in 1927, published in the Report of the Great Barrier Reef Committee vol. III, pp. 58-63, 1931, has been included, showing some changes in the flora and some, also, in the nomenclature.

The Fosberg collections cited were made on October 5-6, 1960, and are deposited in the U. S. National Herbarium. Those of Thorne were made on May 8-9, 1960, and are in the Herbarium of the State University of Iowa, with a set at the Brisbane Herbarium. F. R. Fosberg is finally responsible for the determinations, though preliminary identifications of many of the specimens were made by S. F. Blake, L. S. Smith and R. F. Thorne.

Polypodiaceae

Polypodium punctatum (L.) Sw.

Pot plant seen by Fosberg, 1960.

Pinaceae

Pinus sp.

Very chlorotic seedlings seen by Fosberg, 1960.

Cupressaceae

Cupressus sempervirens L.?

Pot plant seen by Fosberg, 1960

Pandanaceae

Pandanus tectorius Park.

Fosberg 41302, 41325, 41326; Thorne 27210, 27215, 27248.

MacGillivray and Rodway 1931, p. 63, as P. pedunculatus R. Br.

This variable plant is, in Australia, commonly referred to P. pedunculatus R. Br., but seems to be well within the range of variation of the widespread Pacific strand species.

Gramineae

Cenchrus echinatus L.

Fosberg 41336; Thorne 27236.

Digitaria ciliaris (Retz.) Koel.

Fosberg 41310; Thorne 27234.

This species, the tropical representative of the common D. sanguinalis, has been called D. adscendens (HBK) Henr. by Henrard in his Monograph of the Genus Digitaria, but Panicum ciliare Retz. (1786), basionym for D. ciliaris, is earlier than Panicum adscendens HBK (1815), basionym D. adscendens.

Eleusine indica (L.) Gaertn.

Fosberg 41340; Thorne 27238

MacGillivray and Rodway 1931, p. 63.

Eragrostis cilianensis (All.) Lut.

Thorne 27212

Lepturus repens var. subulatus Fosb.

Fosberg 41583, 41343; Thorne 27216

MacGillivray and Rodway 1931, p. 63, as L. repens R. Br.

Spinifex hirsutus Labill.

Fosberg 41330; Thorne 27231

Sporobolus virginicus L.

Fosberg 41313; Thorne 27235

MacGillivray and Rodway 1931, p. 63.

Stenotaphrum micranthum (Desv.) Hubb.

Fosberg 41590, 41331

MacGillivray and Rodway 1931, p. 63, as Stenotaphrum subulatum.

Thuarea involuta (Forst.) R. & S.

Fosberg 41332; Thorne 27217

MacGillivray and Rodway 1931, p. 63 as Thuarea sarmentosa Pers.

Palmae

Cocos nucifera L.

Planted seedlings, seen by Fosberg, 1960

Araceae

Monstera deliciosa Lieberm.

Pot plant seen by Fosberg, 1960

Scindapsus aureus (Lind. & Andre) Engl.

Pot plant seen by Fosberg, 1960

Commelinaceae

Zebrina pendula Schnizel

Pot plant seen by Fosberg, 1960

Liliaceae

Hosta sp. ?

Pot plant seen by Fosberg, 1960

Sansevieria guineensis (Jacq.) Willd.

Pot plant seen by Fosberg, 1960

Marantaceae

Maranta arundinacea L. ?

Pot plant seen by Fosberg, 1960

Casuarinaceae

Casuarina equisetifolia var. incana Benth.

Fosberg 41301; Thorne 27219

MacGillivray and Rodway 1931, p. 63.

Ulmaceae

Celtis paniculata (Endl.) Planch.

Fosberg 41589, 41315; Thorne 27225

Moraceae

Ficus opposita Miq.

Fosberg 41584, 41591, 41318, 41324; Thorne 27227, 27240; Mary E.

Gilham, s.n.; Sydney Univ. Biol. Soc. in 1948

MacGillivray and Rodway 1931, p. 63.

Ficus obliqua var. petiolaris (Benth.) Corner
MacGillivray and Rodway 1931, p. 63 (as F. platypoda var. petiolaris),
described as having complex buttressed trunks.

Ficus sp.

Pot plant seen by Fosberg, 1960

Urticaceae

Pipturus argenteus (Forst.) Wedd.

Fosberg 41588; Thorne 27241

MacGillivray and Rodway 1931, p. 63

Proteaceae

Macadamia ternifolia F. v. M.

Pot plant seen by Fosberg, 1960

Polygonaceae

Rumex vesicarius L.

Cultivated, Fosberg 41341

The sepals lack the marginal nerve characteristic of the more
commonly cultivated R. roseus.

Nyctaginaceae

Boerhavia repens L.

Fosberg 41309; Thorne 27230; Gillham in 1958; Sydn. Univ. Biol. Soc.
in 1948. MacGillivray and Rodway 1931 p. 63, as B. diffusa L.

This strand species, taken in the broad sense, has usually been
called B. diffusa L., but study of the Linnean specimens and of
living material in Ceylon, type locality of B. diffusa, suggests
that the pantropical plant is B. repens L.

Commicarpa chinensis (L.) Heim.

Fosberg 41316; Mauritson in 1936

This species has usually been called Boerhavia repanda Willd. and
the genus Commicarpa should probably be regarded as a section of
Boerhavia. However, since Valeriana chinensis L., the earliest name,
has not been transferred to Boerhavia, the above name is used for the
time being.

Mirabilis Jalapa L.

Planted, seen by Fosberg, 1960

Pisonia grandis R. Br.

Fosberg 41591, 41303, 41317, 41319; Thorne 27233; Sydn. Univ. Biol. Soc. in 1948. MacGillivray and Rodway 1931, p. 63, as P. brunoniana Endl.

Amaranthaceae

Amaranthus viridis L.

Fosberg 41306; Thorne 27239

Portulacaceae

Portulaca oleracea L.

Fosberg 41334; Thorne 27242

Lauraceae

Cassytha filiformis L.

Fosberg 41311; Thorne 27220
MacGillivray and Rodway 1931, p. 63

Berberidaceae

Nandina domestica Thunb.

Pot plant seen by Fosberg, 1960

Cruciferae

Cakile edentula (Bigel.) Hook.

Fosberg 41300; Thorne 27218

Coronopus didymus (L.) J. E. Smith

Fosberg 41338; Thorne 27245

Lepidium virginicum L.

Fosberg 41305; Thorne 27223

Sisymbrium orientale L.

Fosberg 41304; Thorne 27246

Crassulaceae

Kalanchoe sp.?

Pot plant seen by Fosberg, 1960

Leguminosae

Cassia sp.?

Pot plant seen by Fosberg, 1960

Delonix regia (Bojer) Raf.

Planted seedling seen by Fosberg, 1960

Erythrina sp.

Pot plant seen by Fosberg, 1960

Samanea saman (Jacq.) Merr.

Planted seedling seen by Fosberg, 1960

Sophora tomentosa L.

Fosberg 21596

Zygophyllaceae

Tribulus cistoides L.

Fosberg 41308, 41321; Thorne 27229

MacGillivray and Rodway 1931, p. 62

Tropaeolaceae

Tropaeolum majus L.

Planted, seen by Fosberg, 1960

Simarubaceae

Suriana maritima L.

Fosberg 41323; Thorne 27228

MacGillivray and Rodway 1931 p. 62

Euphorbiaceae

Codiaeum variegatum (L.) Bl.

Pot plant seen by Fosberg, 1960

Euphorbia clutioides (Forst.f.) C. A. Gard.

Fosberg 41598, 41327; Thorne 27226

MacGillivray and Rodway 1931, p. 63, as E. eremophila A. Cunn.

Euphorbia cyathophora Murr.

Fosberg 41335; Thorne 27243

Euphorbia prostrata Ait.

Thorne 27222

Euphorbia pulcherrima Willd.

Pot plant seen by Fosberg, 1960

Euphorbia ramosissima H. & A. ?

Fosberg 41599, 41329; Thorne 27221

MacGillivray and Rodway 1931, p. 63, as E. atoto Forst.

It is by no means certain that this plant is really E. ramosissima, as the glands are greenish, rather than white, but it is certainly not E. atoto, and at least superficially resembles the widespread E. ramosissima.

Euphorbia tirucalli L.

Planted, seen by Fosberg, 1960

Malvaceae

Abutilon albescens Miq.

Fosberg 41587, 41320; Thorne 27244; Chadwick in 1951; Gillham in 1958.
MacGillivray and Rodway 1931, p. 61, as A. indicum G. Don.

This has been usually referred to A. indicum L. or A. indicum var. australiense Hochr., but is really much closer to A. asiaticum L. It should perhaps be regarded as a variety of the latter.

Caricaceae

Carica papaya L.

Planted seedlings seen by Fosberg, 1960

Cucurbitaceae

Cucurbita sp.

Planted, seen by Fosberg, 1960

Begoniaceae

Begonia sp.

Pot plant seen by Fosberg, 1960

Umbelliferae

Apium leptophyllum (Pers.) F.v.M.

Fosberg 41333

Plumbaginaceae

Limonium bonduelii (Lestib.) O.Ktze

Cultivated, Fosberg 41342

The leaves of this specimen are unusual for L. bonduellii, more nearly resembling those of L. brassicaefolia. The inflorescence, however, is that typical of L. bonduellii, with linear appendages at the nodes.

Apocynaceae

Nerium indicum Mill.

Planted, seen by Fosberg, 1960

Plumeria rubra L.

Planted, seen by Fosberg, 1960

Convolvulaceae

Ipomoea grandiflora Lam.

MacGillivray and Rodway 1931, pp. 60, 62 (on p. 60 in one paragraph said to have "a large purple flower and leaves often a foot in diameter;" and in a lower paragraph "its flowers were pure white, opening in the evening and closing after the sun rose in the morning," this latter on One Tree Island)

The white flowered species to which this name is commonly but incorrectly applied is Ipomoea tuba (Schlecht.) Don, which is frequently found on coral islands and does not have leaves up to a foot in diameter. I. grandiflora Lam. is probably Stictocardia tiliifolia, which has pale purple flowers and large leaves, but does not usually occur on atolls. Neither were seen by us on Heron Island, nor was any other morning glory.

Ipomoea pes-caprae (L.) Sweet

MacGillivray and Rodway 1931, p. 62

Not seen either by Thorne or Fosberg.

Boraginaceae

Cordia subcordata Lam.

Fosberg 41312; Thorne 27232

MacGillivray and Rodway 1931, p. 62

Tournefortia argentea L.f.

Fosberg 41593; Thorne 27224

Solanaceae

Petunia violacea Lindl.?

Planted, seen by Fosberg, 1960

Solanum lycopersicum L.

Planted, seen by Fosberg, 1960

Solanum nigrum L.

Fosberg 41307; Thorne 27211

Solanum pterocaulon Dunal

MacGillivray and Rodway 1931, p. 63

Labiatae

Salvia splendens Sellow ex R. & S.

Pot plant seen by Fosberg, 1960

Bignoniaceae

Jacaranda sp.

Pot plant seen by Fosberg, 1960

Goodeniaceae

Scaevola sericea Vahl

Fosberg 41595, 41597, 41314, 41322; Thorne 27213

MacGillivray and Rodway, 1931, p. 62, as S. koenigii Vahl.

Most plants seen are of the glabrous form, but with some variation between white and purple in flower color.

Scaevola sericea Vahl (pubescent form)

Fosberg 41328

One clump, represented by Fosberg 41328, is pubescent and has purple flowers.

Compositae

Conyza bonariensis (L.) Cronq.

Fosberg 41339; Thorne 27237

Gnaphalium luteo-album L.

Fosberg 41585

MacGillivray and Rodway 1931, p. 62

Sonchus oleraceus L.

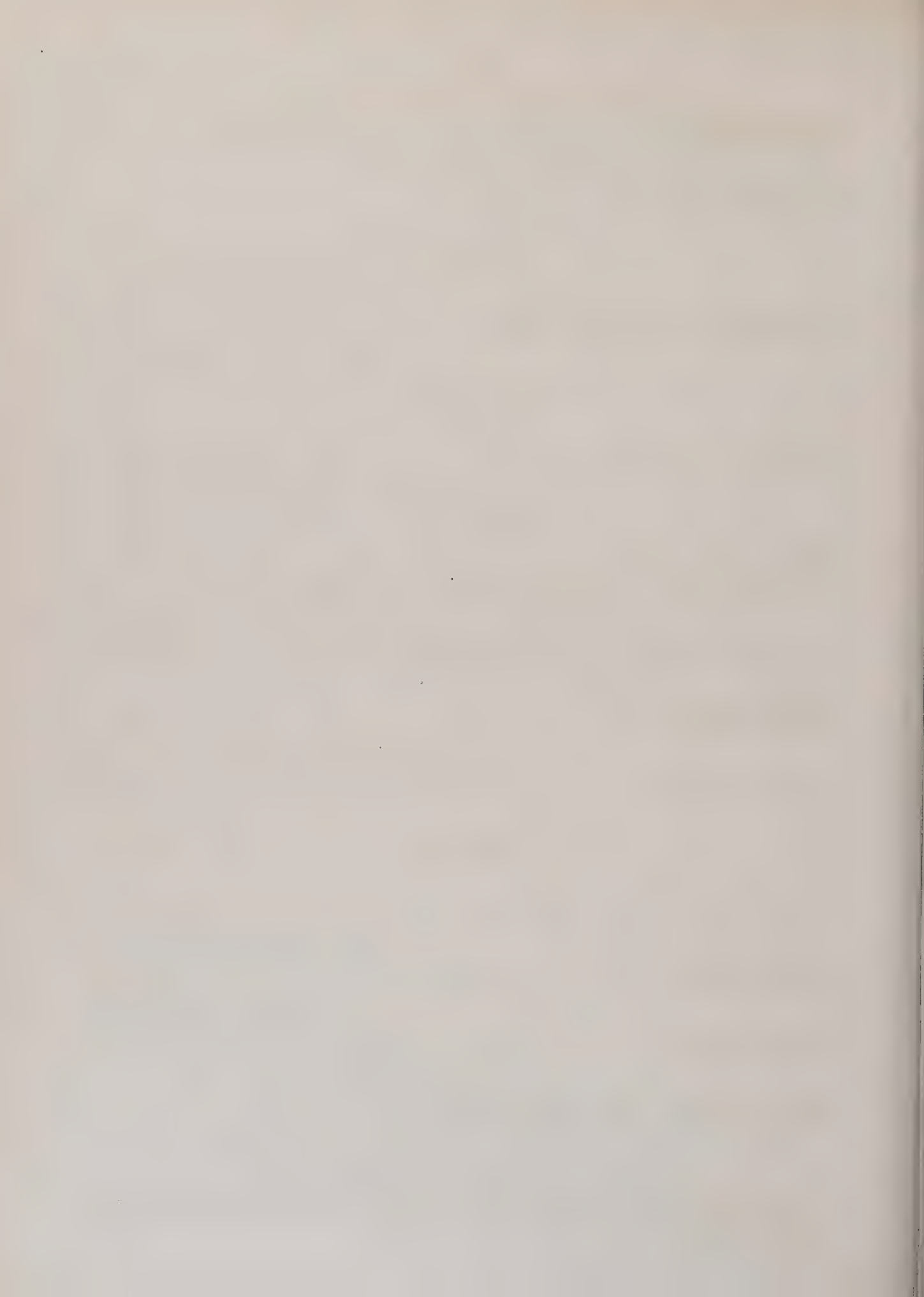
Fosberg 41337

Wedelia biflora cf. var. canescens (Gaud.) Fosb.?

Fosberg 41586, 41594; Thorne 27214

MacGillivray and Rodway 1931, p. 62, as W. biflora DC.

This is not exactly identical with the Guam material on which this variety is based, but until a detailed analysis of the complex is attempted, the canescent-leafed plants are probably best referred here.



III. Some observations on the Heron Island fauna

by

James M. Moulton*

A primary objective of recording underwater sound and of identifying biological sources of some of its components in the Heron Island area has been partially realized during October and November 1960, during which I have been a guest investigator at the Heron Island Marine Research Station, as well as a Fulbright scholar in the Department of Zoology at the University of Queensland. As elsewhere, the primary biological sources of underwater sound are fishes and invertebrates (chiefly alpheids and stomatopods); porpoises (Tursiops) have also been recorded.

The end of the yearly southward migration of whales past the Capricorn Islands occurred in early October. A single unidentified whale was seen thrashing the water west of Heron Island on October 4, and an adult and calf of the hump-backed whale (Megaptera novaeangliae) passed through the channel between Heron Island and Wistari Reef on October 7.

The wedge-tailed shearwaters (Puffinus pacificus) appeared on Heron Island on October 8 and the first calls were recognized during the evening of October 10. The bulk of them will have left the Island by the end of April (H. F. Manning conversation, 1960). According to Island residents, arrival was a bit earlier than usual this year. Numbers mounted rapidly to thousands, the birds settling and burrowing on frequently travelled ground as readily as in less accessible vegetated areas. The burrows are generally about three feet in length and the inner burrow is about 8 inches in diameter. The birds return to the Island at dusk each evening in a great flight; occasional stragglers come in later in the evening.

As of this date (November 17) eggs have not been laid in any burrows examined, and the paired birds frequently remain in the burrow during the day. The events of breeding behavior strikingly parallel those of Leach's petrel in the Bay of Fundy. Another parallel lies in the odor of the oil emitted during breeding from the male bird. The male mutton-bird emits this oil in copious amounts while preening the female.

Other birds abundant on the Island, but less closely observed, are noddy terns (Anous sp.) which have a large rookery in Pisonia trees, reef herons (Demigretta sacra), the nests of which are scattered through the noddy rookery in Pisonia and Pandanus trees, and silver gulls (Larus novae-hollandiae) and crested terns (Sterna bergii) which frequent the beaches but probably do not nest on the Island. There is a white-breasted sea eagle's (Haliaeetus leucogaster) nest in one of the tallest Pisonia trees. A number of other kinds of birds frequent the Island which has a rich bird fauna. Old reef heron nests are at times filled with partially gnawed Pandanus fruits, probably by the island rat Rattus exulans.

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One of the most striking populations on the Island is one of Cerithium monifilerum Kiener, a small gastropod called a clusterwink. This snail behaves with a tidal rhythmicity of considerable interest. On the falling tide individuals of this species aggregate together in dense patches on a flat beachrock surface at the western end of the Island. The clusters are well-formed by the time the water depth is 14 inches; they disperse again on a rising tide when it reaches a depth of about 4 inches over a cluster. During high tide, the snails are dispersed rather evenly over the bottom. Clusters may number from 2 to over 1375 individuals; a few isolated individuals are noted between clusters at low tide, the mean size exceeding that of clustering individuals. The smallest individuals (generally under 6 mm.) do not cluster but are scattered in the sand. The composition of individual clusters varies from one low tide to the next as marking experiments have shown, and the clusters do not always form in the same places on consecutive tides. The clustering behavior is probably a mechanism for retaining moisture during low tide. Individuals in a cluster are in movement during exposure to the sun, so some turnover occurs. A small amount of coral sand is intermingled with the clusters, and a green alga often binds the clusters loosely together. A cluster removed to the laboratory disperses, and individuals move about separately in shallow pans and aquaria.

The mechanisms involved here are of considerable interest; it would, for example, be of interest to remove some of these animals to other areas for a study of relation of behavior to tidal rhythms. As the amount of silt and algal scum varies on different beachrock areas, the populations of Cerithium will vary; increasing surface accumulation decreases Cerithium populations. The clusters are most strikingly formed on flat, denuded beachrock.

Turtles have been late in arriving this year, according to Island residents. The first track was formed on the night of November 11 - 12, and a few turtles have come up since then. As I write this, I have just come from the digging site of a large loggerhead preparing to deposit her eggs within a score of yards of the nearest buildings of the Island resort. While the turtles laying on Heron Island are the green (Chelonia mydas) and loggerhead (Thalassochelys caretta) turtles, a small hawksbill was captured on the reef in mid-October. The latter is said to be uncommon in the vicinity of Heron Island.

ATOLL RESEARCH BULLETIN

No. 83

Notes on some of the Seychelles Islands, Indian Ocean

by

C. J. Piggott

Issued by

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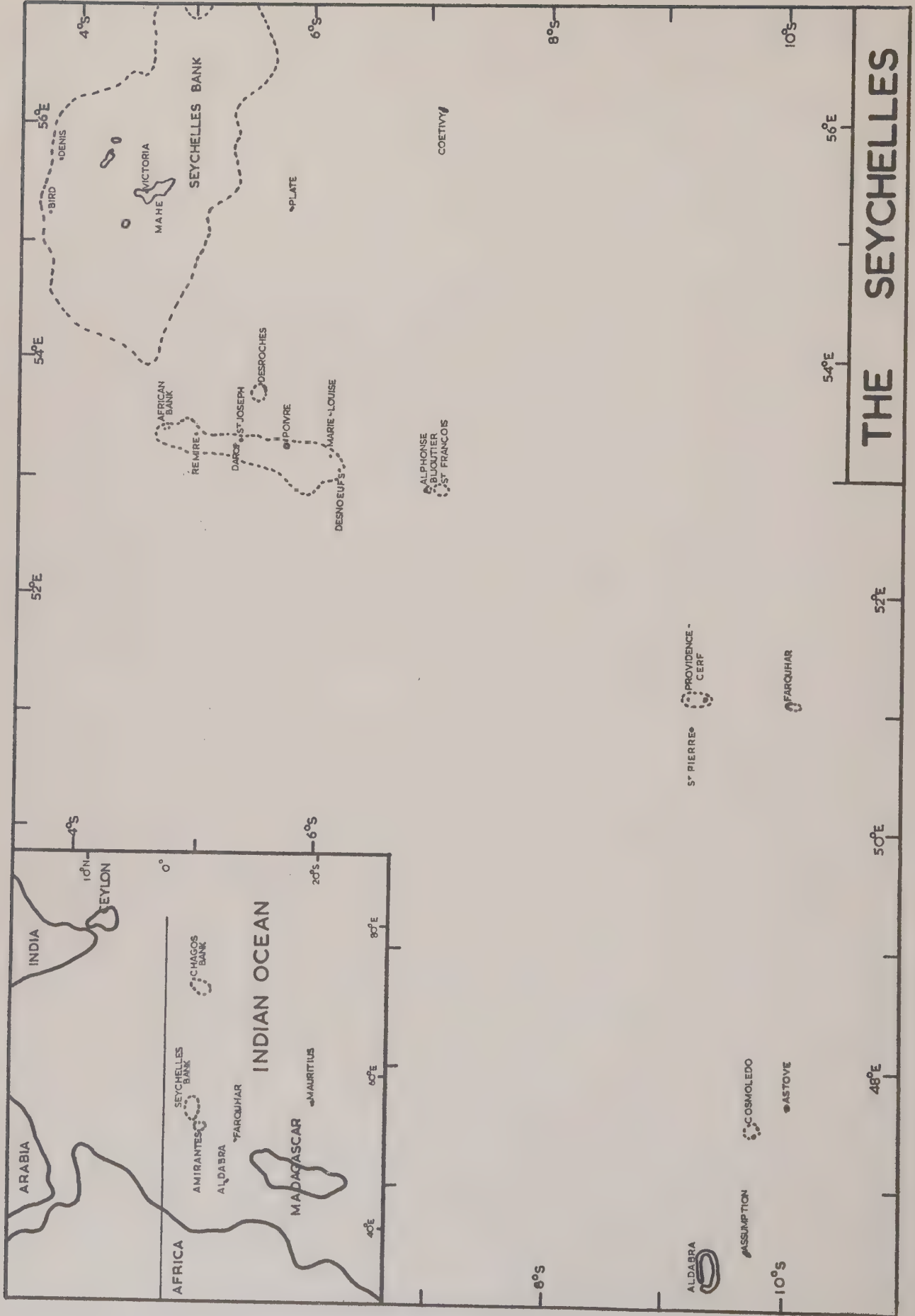
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December 31, 1961







Notes on some of the Seychelles Islands, Indian Ocean

by

C. J. Piggott

Introduction

The Seychelles are a group of islands in the western Indian Ocean (see map), under British Sovereignty. They are scattered over an area of about 150 thousand square miles but the actual land area is only about 100 square miles, 87 of which are accounted for by mountainous granitic islands at the administrative centre of the group, where is the capital, Victoria. Although these are beyond the scope of this paper the economic status of the 'Outer Islands' is dependant on the reservoir of labour and the facilities of exporting produce, which exist on the granitic islands.

The Seychelles Bank is, in effect, a fringing reef of the compact group of granitic islands but is unusually deep over most of this area. The rim is however relatively shallow and at a number of points near enough to the surface to become a danger to navigation. A slight drop in sea level would expose several islands which now only exist as shoals. In two places the bank rises above the surface, giving the islands of Denis and Bird, which are typical of sand cays normally found on atoll rims and are included in this discussion.

A second major bank in the Seychelles, the Amirantes, carries a number of reef islands and atolls, ten in all, with several shoals and submerged reefs. All the other Outer Islands are on separate bases.

Most of the common types of 'coral' island are represented in Seychelles and rough classification based on their morphology is:

Sand Cays (not on atolls, with no sign of recent uplift): Denis; Bird; Daros; Platte; Coetivy; African Banks; Etoile; Boudeuse.

Uplifted Sand Cays (not on atolls): Desnoeufs; Remire; Marie-Louise.

Atolls (with associated sand cays but not uplifted): Farquhar; Providence-Cerf; Alphonse; Bijoutier-St. Francois; Poivre; St. Joseph; Desroches.

Raised Reefs (no lagoon): St. Pierre; Assumption.

Raised Reefs on Raised Atolls (with lagoon): Aldabra; Cosmoledo; Astove.

Islands of the first three groups have an agricultural potential but those in the last two are of little value unless guano is present. Most are privately owned but a few remain as government property and are leased to suitable companies.

The past history of the islands is obscure, although it is known that the Amirantes were discovered by Vasco da Gama on his second voyage of exploration in 1502 and Farquhar was probably seen by Juan de Nova in 1503. Previous knowledge of the islands by Arab and Indian traders is not impossible. They were not charted accurately, however, until 1825 and it was not until the end of the 19th century that they began to have any economic importance. None of the islands have been permanently inhabited. In the early days of exploitation, fishing camps were established and it was probable that guano was discovered at the same time. Similarly, it would be noticed that some islands were suitable for cultivation.

It is proposed in this paper to discuss four typical islands in detail; Alphonse, St. Pierre, Astove and Desnoeufs with a final section dealing with variations to be found on the other islands. Firstly however it is necessary to give a brief reference to the meagre scientific work which has been carried out and to describe the guano and copra industries on which the economy of the islands depends. Not mentioned later is fishing which has, for many years, promised a great future but has never lived up to its promise. Large catches are obtainable near the islands and there is a small trade in salt fish, especially from Aldabra and Cosmoledo. Unfortunately, storage and marketing facilities have always been troublesome and, although a considerable variety of species can be caught and prepared, the export has been dropping and in 1960 only 82 tons were shipped. Without refrigeration and good transport facilities it is unlikely that a valuable market will be developed and it is somewhat galling that the Japanese find fishing in the waters between the islands quite profitable.

Previous Scientific Work

Although brief mentions of the islands had been made previously e.g. in Bojer's 'Hortus Mauritianus', in Coppinger's 'Cruise of the Alert' and in Linell's paper on insects (17), the first detailed study was carried out by the two 'Percy Sladen' Expeditions in 1905 and 1908, which have been reported on by Gardiner and Cooper (1 & 2) and by a series of papers up to 1936 in the Transactions of the Linnean Society, covering mainly the botanical and zoological features. Special mention must be made of two papers by Fryer (3,4) which show the results of detailed research rather than the recording, collecting and systematic work which characterized these expeditions.

Further information, mainly agricultural, has been given by Dupont (5,6) and recently by Piggott (7). Other recent papers of interest are Vesey-FitzGerald on ecology (8) and bird life (9,10) and Ridley and Percy on birds (11,12). Finally a valuable memoir on the geology and guano reserves of the islands is in preparation by Baker (13).

Climate

It is convenient to mention here the climate of the islands. This is dominated by the south-east monsoon of the Indian Ocean which blows strongly and steadily from about the end of April to November and, during

which, the rainfall is negligible. This period has not almost cloudless days with an average shade temperature of about 83°F. The north-west monsoon is much weaker and its effect decreases westwards. At this time the islands experience variable winds and somewhat cloudy conditions. Rainfall is usually torrential but thunder-storms are rare. Although records are scarce it seems that islands eastward of the Amirantes have an annual fall of some 55 inches but this decreases sharply eastwards and on Aldabra it is probably only 15 inches. During the north-west monsoon temperatures are slightly higher, as is the humidity, and without wind the climate can become most trying. It is during this season that cyclonic disturbances occur to the south and the more southerly islands have occasionally suffered severely from their effects.

Guano

Many of the islands had workable guano deposits and, on several, guano formation was continuing when exploitation commenced. The total quantity which has been exported probably approaches half a million tons but relatively little remains now. Guano working started late in the 19th century, peak production being between 1906 and 1930, and still continues, on a reduced scale, on St. Pierre and Astove. The material was found on all types of island and was usually worked by very primitive methods which were, however, profitable. Human activity disturbed the enormous colonies of seabirds and they never returned in quantity and it is only on Desnoeufs and one or two minor atoll islands that guano formation continues. Another loss was the natural vegetation which had to be destroyed before the guano could be scraped up. Except on those islands where coconut planting was possible, the flora, after working ceased, was very limited and the species are now few and of little value.

Coconut Industry

Some coconut planting must have started in the 1870's or so, for it has been reported (1) that the plantation on Farquhar was destroyed by a cyclone in 1893 whilst a photograph in the same paper shows mature palms on Poivre in 1905. Now, all suitable land, and much unsuitable, is planted to coconuts under plantation conditions with little competition from other plants. In the early years yields were poor and not until about 1910 was it realized that special methods of planting and cultivation were necessary on these soils which are inherently infertile and have a low water holding capacity. Since then, yields have improved greatly and compare favourably with those obtained in other parts of the world. As an indication of these yields Alphonse gives annually 2,800 nuts per acre, with the Outer Island average being 1,861. On the granitic islands the yield is only 1,463 nuts per acre per year.

The agricultural technique necessary to produce these yields are (a) good spacing, (b) planting in holes dug to the water table and filled with organic debris, (c) keeping a free root passage to the water table by making holes, similar to the planting holes, close to the palm every 10 years or so, (d) utilizing all trash and husk as mulch, or organic manure and (e) slashing all weeds at least once every year.

The nuts mature on the palm; are collected after falling and converted to copra immediately. After initial rapid drying in locally designed hot air dryers, usually fired by shell and a few husks, the copra is finally sundried to a low moisture content. It is of high quality and stores well, as it must, for local schooners only call at the islands four times a year and there is often several months delay after this before final export.

Pests have been important on most islands especially the scale insects, and their biological control by coccinelids has been spectacular (14). Damage by Oryctes monoceros can be severe but many islands are free of this pest and stringent precautions are taken to prevent its entry. Finally, Poivre and Daros have recently suffered from an infestation by a long-tailed mealy bug, Pseudococcus adonidum, and attempts are being made at present to bring it under control by biological means.

Representative Islands

ALPHONSE

This is a sand cay of some 450 acres, the only land on the rim of a small circular atoll some two miles in circumference (see map). There is a surf-boat passage into the lagoon, which is 15-20 feet deep in most places although there are considerable sand drifts near the reef which are exposed at low tide and emergence of more land is likely. The external reef slope is steep into deep water and the anchorage for schooners is not good, especially during the south-east monsoon.

The shape of the island, roughly an equilateral triangle, is somewhat unusual for an atoll cay but it does confer many advantages, not the least being a large fresh water storage capacity. As is common, the periphery of the island is somewhat higher than the centre but by no more than two or three feet. Beach sandstone is very uncommon with only a small patch near the middle of the lagoon shore. The centre of the island is, however, occupied by a massive layer of phosphatic sandstone which is, in places, over seven feet thick. Around this sandstone and, as far as it is possible to determine, below, the island is composed of uniform coarse sand with gravel only occurring at the points of the triangle.

The soil developed on the sand is a typical Shioya loamy sand (15) with Shioya sand near the coast. Owing to the agricultural development, undisturbed profiles are virtually nonexistent. It is probable that the sandstone in the centre of the island is part of a variant of Fosberg's Jemo Series (16) but with a much thicker than usual cemented layer. Guano, the surface horizon, has been exported but remnants show between 25% and 30% total P_2O_5 and its pH (colorimetric) varies between 5.7 and 7.0. The phosphate content of the rock slowly decreases downwards but the pH increases to about 8.0 within a fraction of an inch below the rock surface. The rock is pervious, and water can percolate down occasional cracks, but it forms an effective barrier to root penetration. There is no rock below the water table, which is at roughly the same level as in the sand.

KEY

HORIZONTAL LINES — LOAMY SAND SOIL

VERTICAL LINES — AREA OF PHOSPHATIC SANDSTONE

C C C C — ZONE OF ISOLATED CORAL HEADS

THE LAGOON HAS A MAXIMUM DEPTH OF ABOUT SIX FATHOMS. THE SEA IS MORE THAN 100 FATHOMS DEEP WITHIN A QUARTER MILE OF THE REEF FRONT

REEF FLAT

REEF FLAT

SAND DRIFT

PARTLY EXPOSED AT LOW TIDE

LAGOON

REEF FLAT

ENTRANCE TO LAGOON



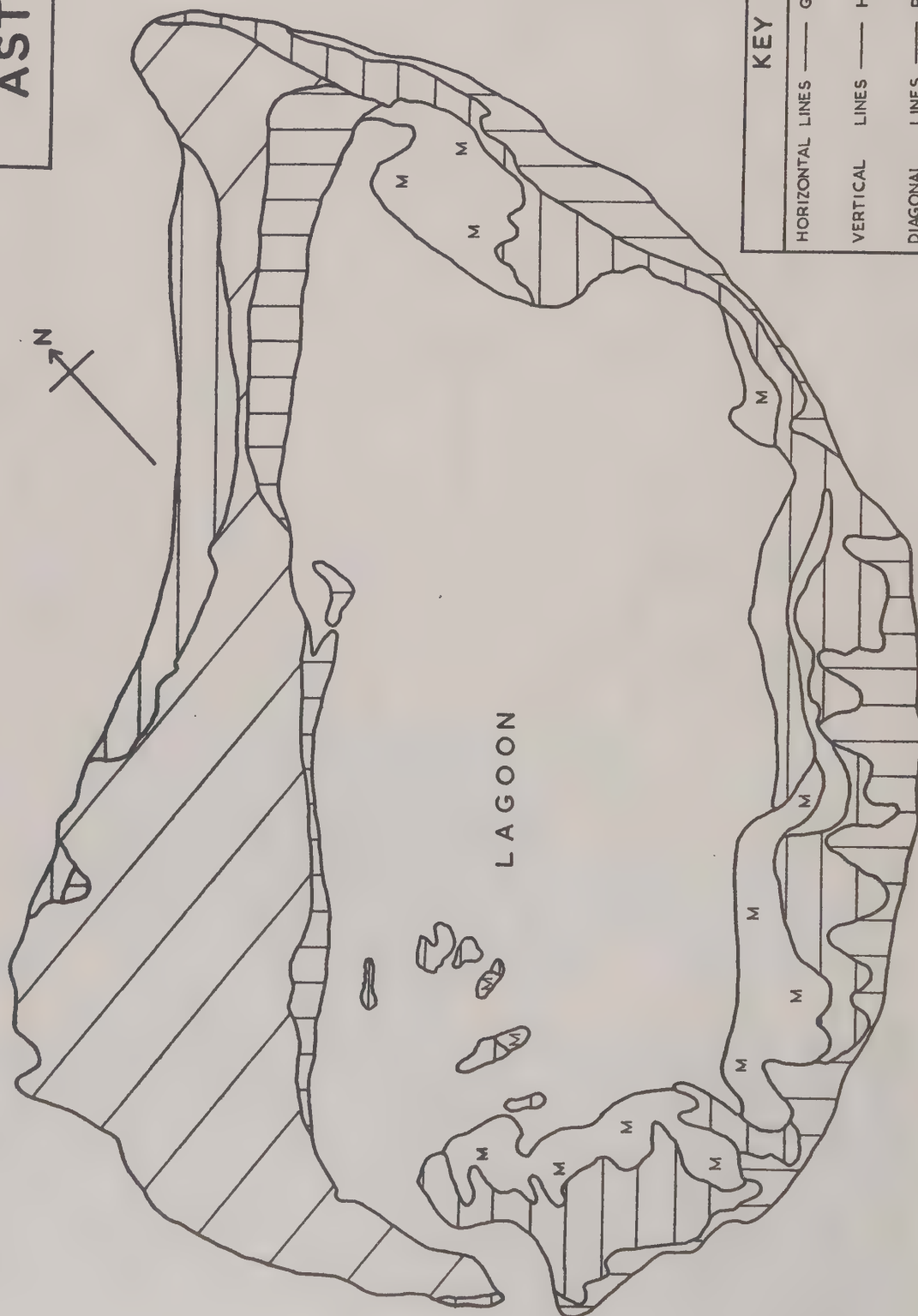
TWO MILES

ONE MILE

0

ALPHONSE

ASTOVE



KEY

HORIZONTAL LINES	GRAVELLY SAND
VERTICAL LINES	HIGH DUNES
DIAGONAL LINES	REEF ROCK
	CORAL MUD WITH PEMPHIS ACIDULA

As mentioned previously, it was inevitable that the natural vegetation should be destroyed during guano exploitation on the sandstone area whilst most was lost on the sand during coconut planting. There remains a much broken fringe of Scaevola sericea around the shore line and this is probably the only species left in its natural habitat. Occasional mature specimens of Hernandia sonora can be found but whether they formed part of the natural vegetation is difficult to determine. Other than coconut, the most noticeable tree is Casuarina equisetifolia which has certainly been introduced. This was planted over much of the island but has now been reduced to a pleasant avenue across the island and a wind break in the south-west. Alphonse is unusual in this respect for many coconut islands have an almost complete wind break of Casuarina. The only other tree which seems to thrive is Terminalia catappa. Exotic fruits such as the mango are absent, as is Pandanus.

Under the palms on the Shioya loamy sand, the vegetation is mainly low grass of several unidentified species although amongst them Stenotaphrum complanatum is common. On the sandstone a mixed population of low herbs is found, almost all introduced weed species, including Acalypha indica, Solanum nigrum, Commelina benghalensis, Tylophora asthmatica, Ricinus communis and Catharanthus roseus. Most characteristic, however, is Carica papaya which now grows wild and is an infallible indicator of the presence of phosphatic sandstone, even if this has been buried by sand.

In view of the negligible soil and poor water relations on the sandstone areas, palms do not thrive but, in selected places, annual crops can be grown with some success if the rainfall distribution is reasonable. Maize, pumpkin and sweet potatoes are carefully cultivated by the labourers and make a pleasant change in the otherwise monotonous diet. The high overall yields of coconuts given previously are confirmed by individual nut counts and an average over 165 random palms is 36 nuts per palm. Symptoms of potassium and iron deficiency are common whilst phosphorous is at a low level in the sandy soil so that, by careful manuring, it should be possible to increase even these good yields. Fertilizer trials are in progress with such an improvement beginning to show.

ST. PIERRE

This island, about $3/4$ mile in diameter with an area of 417 acres, has been one of the most valuable of the group owing to its guano and high grade phosphatic rock. It is a raised reef and the surface consists of corals and calcareous algae in position of growth but much weathered. The uplift is greater than on any other island of this group and the surrounding cliffs are some 30 feet high although the centre of the island is more or less at sea level. These cliffs are undercut and fretted by wave action, for there is virtually no fringing reef, the swell breaking against them. Owing to the cavernous nature of the island there are many coastal caves and a number of these have 'blowholes' which have given rise to a characteristic feature of the island: coastal sand dunes, some ten feet high, behind each blowhole, built from the debris thrown out by the jet of water.

Although the wave action does not penetrate more than 30 yards inland, the inter-connecting caverns honeycomb the whole island and at the water table is, invariably, sea water. At one time the whole island was covered with guano and this has resulted in a considerable phosphatisation of both the coral rock and any drifts of sand which were present on uplift. At least 150,000 tons of high grade guano have been removed whilst in recent years the rock has been crushed and mixed with the guano giving a standard export grade of product with 22.5% P_2O_5 at a low moisture content. Small deposits of guano are still being found in caverns where it has been washed by rain.

Prior to guano exploitation the island had a mixed vegetation with a bank of Pemphis acidula along the coast and, behind, a scrub with Pisonia grandis, Cerbera odollam and Hibiscus spp. predominating (4). Now it is almost a desert. On the east coast a few scattered Pemphis bushes still exist whilst only two, extremely battered specimens of Pisonia have been left in the centre of the island. Of the herbs which survive on the remains of the soil, Stachytarpheta indica is the most common. A surprising introduction which appears to be establishing itself is Gaillardia pulchella and this relieves the monotony of the colouring during the dry season. On the blowhole 'dunes' there is a thick mat of Sporobolus virginicus. Around the settlement several exotics have established themselves including Datura stramonium, Asystasia gangetica, sisal and a few pawpaws and bananas. Nearby, a partial windbreak of Casuarina equisetifolia has been planted and this, surprisingly, is thriving and spreading.

The island has, obviously, no agriculture potential and no food crops are grown. It can only be hoped that, when guano exploitation has finished, the birds will return or the Casuarina spread over the island. Otherwise it is likely to remain a desert.

ASTOVE

Astove (see map) has been classified as a raised atoll but it is not impossible that the shallow lagoon has been formed by solution for, as suggested by Fryer (4), it is rapidly widening and deepening. This lagoon, which is only about ten feet deep at the maximum, has an entrance, some 200 yards wide, only about two feet deep at low tide. The lagoon water has a high concentration of suspended calcium carbonate which is flushed out on a falling tide, and this gives the water an opacity similar to that of milk. Other than the single entrance, the lagoon is land locked. The atoll is surrounded by a fringing reef some 200 yards wide with an exceptionally steep outer slope, the water being over 100 fathoms within 100 yards of the reef front.

The maximum elevation of the reef rock is some 15 feet but, owing to the rapidity of solution, the actual uplift must have been much greater. The reef rock is only exposed in quantity on the west limb of the island; the base of the remainder being somewhat lower and composed mainly of gravelly reef debris. On this debris has been developed a line of coastal sand dunes over fifty feet high and drift from these has given a shallow

cover to the gravel. Similar, but much lower, dunes have been formed on the leeward lagoon shore. All the dunes appear to be stable at the present time, although there is some superficial movement of sand grains during high winds, and they have a fairly good plant cover. The presence of dunes on the five southerly island groups only, indicates that the effects of cyclonic disturbances are important in their formation.

As on St. Pierre, the reef rock of Astove is cavernous and large quantities of the surface guano were washed into these and redistributed by the sea water. Although sporadic workings have taken place there probably remains an exportable weight of guano hidden in undiscovered caves. There remains little trace of the original vegetation in this rock area but trees of Pisonia grandis still occur, with occasional Sideroxylon inerme. More important is a herb 'mat', which thrives where there is any soil remaining, with Plumbago aphylla predominating and including Dactyloctenium pilosum and Stachytarpheta spp. Sisal and wild cotton also exist on the very thin soil.

On the western limb, both coastal sandy areas have been planted with coconuts which are, unfortunately, not thriving. Owing to the height of the ground surface above the water table the palms have difficulty in obtaining moisture during the dry season and they suffer badly from wind damage. Admittedly, there is no wind break and the palms are growing on exceedingly rocky land at the edge of the reef rock area and it is possible that these are tapping water supplies and nutrients from the caverns below. There is certainly no soil on the rocks.

The soil of the dunes approximates to the Shioya Sand (15) but should probably be in a 'series' of its own, as the grain size is remarkably uniform and the agricultural potential is low owing to the limited water retention. The gravel flats have a very gravelly variant of the Shioya Loamy Sand, there being a considerable variation in the textural profile with depth owing to an admixture of wind blown material. This soil is probably suitable for palms as it can retain a reasonable quantity of water but little planting has been attempted owing to the absence of a windbreak - the dunes themselves not being effective enough. Excellent crops of maize have been obtained occasionally however.

The natural vegetation of these dunes appears to be a mat of Sporobolus virginicus in the spray zone and above this desiccated wind-moulded shrubs of Suriana maritima. Where the exposure is less, Scaevola sericea and Tournefortia argentea come in with very occasional Pisonia grandis. Clumps of Fimbristylis form a scattered ground cover whilst Cassytha filiformis is common, climbing over all and sundry. On the gravel flats the predominant vegetation is a mixture of drought resistant grass species including Stenotaphrum complanatum. Near the lagoon Pemphis acidula occurs and there are occasional specimens of Avicenia marina; but these do not thrive in the milky water.

The potential of this island has never been exploited; the main interest in the past being guano which can now only be collected as a sideline. A little commercial fishing has hardly paid its way whilst interest in agriculture has only been sporadic. Coconut planting is possible, if suitable windbreaks are established first, on much of the sand

and gravel soil whilst annual crops such as maize will give good yields if properly looked after. The only real problem is the chance of a cyclone which could destroy all the work.

DESNOEUF

This uplifted sand cay, of some 86 acres only, is the only example of a virtually untouched island in the group. It is nearly circular with a maximum height of about 18 feet but, as usual, is saucer shaped, the centre being 7 feet above high water. There is no lagoon, only a fringing reef, and the reef flat is narrow. On top of this are many irregular blocks of beach sandstone which have been broken away from the more continuous sheets on the island edge. The landing, even by surf boat, is extremely hazardous and this is one of the reasons why the island has not been exploited.

The geologic structure is complicated. From the air can be seen a series of white concentric rings which stand out against the brown and green of the soil and vegetation. Ground inspection shows these to be outcrops of apparently typical beach sandstone with an angle of dip approximating to 25°. Between them is sand. This sandstone is only formed by precipitation of calcium carbonate, when a saturated solution comes into contact with a saline groundwater and must indicate previous coastlines of the island. It is probable that each outcrop coincides with a different stage of uplift, the older one having lost much material by solution. The original stable sand cay was, therefore, about 100 yards in diameter. Outside the visible sandstone outcrops is a coastal sand-dune, formed from reef debris carried inland under storm conditions. Doubtless this covers further outcrops for similar intact sandstone is found exposed at the boulder zone. It is of interest that a similar structure is found on Marie Louise, only seven miles away, but there it is obscured by the luxuriant vegetation.

The vegetation on Desnoeufs is not luxuriant. It is depressed as the result of the presence of numerous sea birds. Ridley (11) estimated that a million and a quarter breeding pairs of terns congregate there in addition to numerous boobies and 'fouquets' (Procellaria pacifica hamiltoni). In the past an export of preserved egg yolk was permitted and in one season over 1,500 gallons were shipped. Nowadays the island is a bird sanctuary and egg collection is only allowed every alternate year, when over one and half million eggs are sent to the central island where they form a major item in the diet. Surprisingly, this has made little or no difference to the total population. There is a fairly thick layer of guano on the ground and its formation is continuing. At the same time the sand and the beach sandstone are becoming phosphatized.

As can be expected, only a few plant species can survive the steady rain of bird excreta during the dry season. Even the normal coastal scrub of Scaevola sericea is limited to half-a-dozen stunted bushes. An unidentified tufted grass exists on part of the coastal dune but the remainder of the vegetation is limited to either short lived annual species which can seed before the bird concentration becomes too great

or to very tolerant perennials. The commonest plant is Stachytarpheta but the total number of species is only about ten. There are certainly no trees, with the exception of a small clump of some twenty coconuts which are struggling to survive in the centre of the island.

Possibly a little of the guano has been exported as there is some evidence of workings but the quantity must have been very small. Again an attempt has been made to plant coconuts as sites of planting holes can be seen on the aerial photographs (but not on the ground). Whether these holes were once planted is impossible to determine but certainly only the palms mentioned above survive.

THE OTHER ISLANDS

The geological classification of the other islands has been given previously. Within each group the islands are superficially similar but differ greatly in detail. The larger sand cays are all used for coconut production as individual plantations and all but the most youthful have some remaining guano and phosphatic sandstone. Bird and Coelette on Farquhar atoll, are the only large cays with a significant sea bird population. The former was the site of a very large ternery fifty years ago but exploitation of guano and the beginning of agricultural development caused the disappearance of birds from all but a few acres on a very recent sand spit. The very small cays have not been exploited and are still nesting sites for some birds, and will be valuable if they increase in size by accretion of sand. The biggest sand cay is Coetivy with an area of over $3\frac{1}{2}$ square miles, the smallest cultivated one being Bijoutier which is only two acres. The atoll islands are similar to the sand cays but the adjacent lagoons vary considerably in depth. For example, it is only possible to enter St. Joseph lagoon by dragging a boat over the reef but the lagoon is deep and provides excellent fishing; Farquhar atoll has a deep water entrance and schooners can moor against a short pier on the main island in sheltered water but the lagoon is fairly shallow and abounds in coral 'heads'; whilst Desroches is on a submerged reef which can only be discovered by sounding, its lagoon having a maximum depth of 17 fathoms.

The raised atolls and reefs are scientifically more interesting but economically of little value. Aldabra, for example, is one of the two remaining island groups in the world inhabited by species of Giant Tortoises, (Testudo gigantea), the other being Galapagos, but, apart from mangrove poles and its use as a base for fishing and catching turtles, it has no immediate value although the land area is considerable. The same applies to Assumption and Cosmoledo, although guano was exported from them in quantity once. Certainly, where there is no soil there can be little agriculture.

Summary

The Seychelles Outer Islands show features common to many atoll groups of the tropics but the variations in relative uplift are large for such a small area. The natural fauna and flora have been modified by the guano exploitation and coconut plantations.

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ATOLL RESEARCH BULLETIN

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Atoll News and Comments

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Atoll News and Comment

Although the intention was to include, in each issue of the Bulletin, a short section on items of current interest, various circumstances made it inconvenient to do so in the last several issues. Hence the present article is more extensive than intended and some of the items are decidedly out of date. It is hoped that this will not occur in the future. It is also hoped that readers will continue to send in current items of interest to those concerned with coral atolls.

The present issue of the Atoll Research Bulletin has been seriously delayed and, consequently, some of the articles have been on hand for a deplorably long time. Apologies are hereby offered to the authors.

Recent and current investigations

Christmas Island:

Considerable work is either in progress or planned on Christmas Island, taking advantage of its status as an atomic proving ground, with attendant ease in communication and availability of facilities. Dr. David I. Blumenstock made a fairly extensive visit there in June 1960, studying weather phenomena and hydrography. He plans another visit as soon as circumstances permit. Dr. Philip Helfrich of the University of Hawaii, makes frequent visits, working on marine biological problems. Mr. Philip Ashmole, of the Edward Grey Institute, Oxford University, is planning an extended expedition to Christmas Island in 1962 to study the breeding cycles of sooty terns and other sea birds and to relate them to seasonal fluctuations of plankton abundance in the waters around the island.

Leeward Hawaiian Islands:

Prof. M. D. F. Udvardy, of the Zoology Department, University of British Columbia, writes of an 8 day expedition to Laysan Island in July 1959. The party included, in addition to himself, George D. Butler, Jr., Richard E. Warner, and Charles Daniel. Investigations included work on entomology, observations on behavior and a census of monk seals, observations on Laysan duck and finch, shearwaters and other birds, weather observations, collection of the flora, and vegetation mapping. Observations were made in relation to the nature and development of biotic communities. It is of interest that Dr. Udvardy seems to concur with our idea that the simplicity of atoll biota may help in understanding biotic communities generally. We are looking forward with great interest to the series of papers planned to report the results of this expedition.

As a continuation of the above mentioned observations, a 10-man expedition visited Laysan following the Tenth Pacific Science Congress, September 1961. Participants were Dr. A. Starker Leopold, Dr. Miklos D. F. Udvardy, Dr. Robert L. Usinger, Dr. George D. Butler, Jr., Dr. Charles H. Lamoureux, Dr. Martin Vitousek, Mr. Edward C. Jestes, Mr. Richard E. Warner, Mr. David H. Woodside and Mr. Ronald L. Walker. In addition to a week on Laysan, short visits were made to Kure and French Frigate Shoal. Transportation was furnished by the U. S. Coast Guard.

Midway Island--albatrosses and the jet age:

We can report that, as of October 2, 1961, the threatened slaughter of gooney birds on Midway Island by the U. S. Navy has not yet taken place. When the plan to eliminate these albatrosses because of the hazard of collisions between them and planes was publicized in 1959 such a protest arose from organizations and individuals that the action was deferred. Investigations were carried out to see if the birds could not be frightened or coaxed away from the runways.

A number of ideas were tried out, including the use of various noise-makers, smoke, and "habitat improvement" on nearby Kure Island, designed to attract the Midway albatross population to Kure. These had little or no effect. Leveling the small dunes near the runway and asphaltting the ground, to eliminate the updrafts of air on which the birds soar and to make the ground unattractive for the birds, was also initiated. These measures were remarkably successful, in terms of reduced number of birds soaring over the runway and in terms of reduced number of collisions with planes. If and when this operation is completed, it may eliminate the collisions without eliminating the birds. The other measures do not seem to be promising. We hope that the suggestion of planting Casuarina on Laysan and other nearby atolls "to make them more attractive to the albatrosses" will not be carried out.

In the summer of 1961 Dr. Harvey I. Fisher studied the Midway albatrosses, both from the standpoint of population dynamics and that of experimenting with possible "imprinting" of young birds by moving them to a new location, to see if they tend to return to the new location for breeding when they reach maturity.

One of the disturbing things reported by Mr. Chandler Robbins, Fish and Wildlife Service biologist who has been handling the Midway investigation, is a general irritation among the personnel stationed at Midway with the noises made by birds of various sorts and especially with the burrowing habits of the shearwaters. This has resulted in a certain amount of killing and harassment of the birds. There may be some connection between this and the reported recent reduction of the Midway albatross population, attributed to accident and vandalism. It appears, as also demonstrated by the negative correlation between people and sea-birds in the Marshall Islands, that sea birds and people do not very successfully occupy the same habitats.

Mr. Robbins has prepared a report on the success of leveling experiments and on the current situation involving these birds which will soon be issued in the Fish and Wildlife Service Special Scientific Reports; nos. 38, January 1958, and 44, July 1959 includes earlier information.

Wake Island:

In September 1961 after the Tenth Pacific Science Congress, Dr. Bruce Halstead, director of the World Life Research Institute, conducted a scientific party to Wake Island to collect poisonous fish, in continuation of his previous studies of the "ciguatera" poisoning problem. Participants were Dr. and Mrs. Halstead, Drs. Donald Hessel and Richard Beltz, chemists, Messrs. Don Ollis and Robert Rutherford, photographers

and Miss M.-H. Sachet. The latter concentrated on the land ecology of the atoll, continuing observations made by F. R. Fosberg in 1951, 1952 and 1953 (see ARB no. 67, 1959). Insects and some reef animals, soil samples and especially herbarium specimens of land plants were collected.

Jaluit Atoll:

A follow-up study of the recovery of Jaluit from the effects of Typhoon Ophelia, January 1958 (see ARB 75) was undertaken in October 1960, by a party composed of Dr. David I. Blumenstock, Charles G. Johnson, Harold Rehder, and F. R. Fosberg, again under the auspices of the office of Naval Research and the Pacific Science Board. Marked changes were noted in some aspects, though the results of the typhoon are still very obvious in others. Coconut replanting has been completed and the economy of the people is well on its way back to normal. A preliminary note has been published summarizing the results of this visit (Nature 189(4765): 618-620, 1961) and it is hoped that a more extensive report can be completed soon.

Rongelap Atoll, Marshall Island:

As noted in Atoll Res. Bull. 70. p. 3, the University of Washington Radiation Biology Laboratory has extended its studies of fallout-contaminated areas in the northern Marshall Islands to some of the terrestrial aspects of the problem. Repeated expeditions under the direction of Dr. Edward E. Held have visited Rongelap Atoll and information on radioactivity levels in soils, land animals, and land plants has been collected. A detailed study of the soils of the atoll has been undertaken, and some experimental work to detect possible effects of low level radioactivity on plants has been done. Conversation with members of several of the expeditions indicates that the morbid appearance of many of the plants in the vegetation of the northern islets of Rongelap, observed in 1956 and reported in Atoll Res. Bull. 61, 1959, has persisted. This has been the object of some attention by the group, but as yet no convincing explanation has been advanced.

A paper by R. F. Palumbo and F. G. Lowman on the occurrence of antimony-125, Europium-155, Iron-55 and other radionuclides in Rongelap Atoll soil, has been issued as Report no. UWFL-56, by the Technical Information Service Extension, Oak Ridge, Tenn. At the IXth International Botanical Congress, Montreal, August 1959, R. B. Walker and E. E. Held presented a paper on radiocaesium in plants grown on Rongelap Atoll soils. R. F. Palumbo presented one at the same occasion on the differences in uptake of radioisotopes by marine and terrestrial organisms. Held has since published an abstract on Observations on two land crabs in the Marshall Islands (Bull. Ecol. Soc. Amer. 41: 51-52, 1960), presented at the meeting of the Ecological Society of America, Western Section, Eugene, Ore., June 14, 1960. It may be noted that the "crabs" referred to are the coconut crab and a hermit crab, rather than land crabs. S. P. Gessel, E. E. Held and R. B. Walker presented a paper on nitrogen studies of Rongelap atoll soils at the Tenth Pacific Science Congress. Other results should not be long in coming.

The notes on the condition of the vegetation on the northern islets of Rongelap by Dr. Baruch Blumberg, mentioned in ARB 70, p. 3, have been published by Blumberg and Conard as an addendum to a report by Conard, et al., on a Medical survey of Rongelap people five and six years after exposure to fallout, BNL 609 (T-179), pp. 85-86, 1960. Since this paper was published in a very obscure place, not likely to be seen by any student of atoll vegetation, it is reproduced below,* minus the map and photo.

These observations and those mentioned above by the radiation Biology Laboratory scientists make it obvious that the abnormal condition of the vegetation of the northern Rongelap islets is not merely a temporary phenomenon induced by climatic vicissitudes or accidental wave wash, and that the cause is not known. While we do not insist that there is any connection with the Castle fallout, as suggested in ARB 61, no better explanation seems to have been offered, at least none that is satisfactory to those familiar with the normal character and behavior of atoll vegetation. We have not seen any detailed outline of the plans and procedures of the present ecological study by the Radiation Biology Laboratory group, but there seems to be no indication that several of the possible lines of approach previously suggested to the U. S. Navy Radiological Defense Laboratory and by them to the AEC have been tried. Although so much time has elapsed that much of the evidence may have been lost, it still would seem appropriate to study in detail the condition of individual plants of the most affected species, of all ages from newly germinated seedlings to old and obviously injured plants, to excavate root systems and find whether the poor condition of the shoots is matched by corresponding pathology of the roots, to determine, histologically, the nature of the injury and the tissues affected, and to see if there is any unusual concentration of radioactive substances in these or any other tissues in the injured plants. There seems little point in devoting any more attention to Scaevola and Tournefortia (Messerschmidia), since both the Fosberg and Blumberg reports note that these plants completely failed to show the pathological conditions observed in other species. Finally, a detailed survey of the present condition of all species of plants on the different islets of Rongelap, by someone who is thoroughly familiar with their normal appearance under similar climatic conditions, should obviously be made and published so that an unbiased assessment of the situation could be made by anyone interested. It may be added that the pages of this Bulletin are open for preliminary publication of any available data on this problem and that such publication might serve an immediate purpose in stimulating new ideas.

*A note on the vegetation of the

northern islets of Rongelap Atoll, Marshall Islands, March 1959

B. S. Blumberg and R. A. Conard

"Fosberg^{1,2} reported changes in the vegetation of the northern islets of Rongelap Atoll (observed in 1956) which he inferred might have been associated with the radioactive fallout that occurred on this atoll in 1954. During the medical survey of the Rongelap people³ carried out in March 1959, an opportunity arose to visit some of these islets and to

re-examine the vegetation. A helicopter was available for transportation, which permitted general and detailed air examination as well as two short ground surveys. The northern islets were estimated to have received a radiation dose of ~3000 r. The islets of Naen and Gegen were examined in greatest detail. The most striking feature observed from the air was the generally gray color of much of the vegetation, in contrast to its normal green color. Ground surveys revealed that Scaevola sericea was common and normal in appearance. Many of the Guettarda speciosa appeared to be in poor condition (Figure A-2). In some, all or nearly all the leaves were gone from the terminal 1 to 12 in. of the branches, and other leaves were yellowed and shriveled. In other Guettarda, nearly all the leaves were gone, and the bushes appeared completely dead. More than 50% of the Guettarda were affected in whole or part. In one area of Naen several hundred yards inland from the ocean beach, there was a field of ~30 Guettarda, all of which were dead. Some young Pisonia grandis were seen which appeared to be in good condition. Mature Pisonia were seen which were partially defoliated, but these did not appear to be greatly different from those seen on Rongelap Islet on the southeast corner of Rongelap Atoll. None of the mistletoe-like clumps described by Fosberg were observed. Several Ochrosia oppositifolia were seen with nearly complete defoliation, which appeared dead. A small grove of coconut trees near the center of Naen Islet contained 4 to 5 dead trees within a radius of ~300 yards, which were decapitated at heights 5 to 12 ft above the ground with no evidence of axe or machete marks. Two 2-headed coconut trees were seen, one with fronds that were mostly brown and appeared dead growing from the trunk ~12 ft below the true crown of the tree. Several trees had dry and shriveled fronds, and ~6 had deformed bulges 4 to 8 ft below the crown with apparently normal growth above the bulges.

"Photographs of the affected vegetation were examined by Dr. Fosberg, and he stated that the changes were similar to those he had previously reported.

"It is not possible to evaluate the cause of the changes from the present observations. More extensive and detailed botanical and ecological surveys will be necessary, both on the islands that received radiation and on those that did not, to determine whether the changes seen bear any relation to fallout. In particular, it should be noted that these observations were made during the dry season.

"We are indebted to Professor Frank Richardson of the University of Washington for identifying the plants, and to Commander W. Lyons, USN, for his assistance in taking the photographs.

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Caroline Atolls:

During the summer of 1960 Dr. Harvey A. Miller, of Miami University, Oxford, Ohio, led an expedition to collect material and to study certain aspects of cryptogamic botany and wood anatomy on the Caroline Islands. The active personnel on this trip were Dr. Miller, Henry O. Whittier, Less S. Dutton, Ernani G. Menez, and Alnus Oruetamor. The schooner Collegiate Rebel served as base of operations and transported the party between islands. Extensive collections of bryophytes and marine algae, and some wood samples with herbarium vouchers were prepared. The wood samples were shipped to the U. S. National Herbarium, the bryophytes to Miami University, and the algae to the University of Hawaii. In addition to the high islands a number of atolls were visited, including Mokil, Oroluk, Namonuito, Puluwat, Ifaluk, Sorol, and Pulu Anna. An outcome of this investigation is the undertaking, by Mr. Whittier, of the preparation of a bryoflora of the Micronesian atolls. In addition to the collections mentioned above, which were the principal objectives of the trip, Dr. Miller informs us that a collection of vascular plants was made on Mokil.

Ulithi Atoll:

On November 30, 1960, Ulithi was hit by Typhoon Ophelia (second of this name in Micronesia) and badly battered. In view of the interest of the Coral Atoll Program in the effects of typhoons on atolls, the Pacific Science Board and the Office of Naval Research sent a party made up of David I. Blumenstock, Charles G. Johnson, and William A. Lessa to Ulithi in January 1961, to survey the damage. Since Lessa had previously done ethnological work on Ulithi it was especially fortunate that he could be a member of the party. A summary of observations is being prepared for publication in Science, and it is hoped that a full report may be available for this Bulletin in the not too distant future.

Laccadive Islands and Minicoy:

Information has been received, through the Unesco Humid Tropics Programme, that the Botanical Survey of India, Western Circle, has carried out a collecting mission to the Laccadive and Minicoy atolls. No further details are available except that the herbarium specimens received have been incorporated into the Western Circle Herbarium, at Poona.

Alacran Reef:

Although the Pacific Science Board's Coral Atoll Program has functioned mostly in the Pacific, its scope extends throughout the tropical areas where coral atolls and similar islands exist. Therefore it is with great interest that we call attention to rather extensive studies of Alacran Reef, north of Progreso, Yucatan. The vegetation of this atoll was described in some detail by C. F. Millsbaugh following a visit in 1899.

From 1955 to 1961, a number of expeditions from various institutions have visited and worked on Alacran, making it, by now, one of the better known atolls. Most of this work is as yet unpublished but several manuscripts are in press, including one by F. Bonet and J. Rzedowski on the

vegetation and one by L. Huerta Masquíz on the marine flora which have been submitted for publication by the Escuela Nacional de Ciencias Biológicas in Mexico City. Louis Kornicker and colleagues have published an excellent map of Alacran Reef and a general descriptive paper, including preliminary lists of animals found there (Inst. Marine Sci. Pub. 6: 1-22, 1959).

Work carried out during the summers of 1959 and 1960 may be indicated by quoting as follows from a letter, dated March 28, 1961, from Dr. J. T. Conover, chief scientist of the Duke University party:

"A bio-geological survey of Alacran Reef, Yucatan, was undertaken by the University of Texas and Duke University as cooperating institutions each supported by separate National Science Foundation grants (U. of T., NSF-G 8902; Duke U., NSF-G-12333). An account of the objectives and work of the University of Texas group in 1959 is given in a paper by Kornicker, Bonet, Cann and Hoskin in Vol. 6, 1959, Publ. Inst. Mar. Sci. The objectives of Kornicker's group were to study the biogeologic genesis of a living reef and later to compare the results with fossil reefs and paleoecological considerations.

"The first summer (1959) Kornicker's group devoted their time to a general survey of Alacran atoll with emphasis on the geological features, the atoll profile and the general nature of the living communities. The second summer (1960) Kornicker and Boyd concentrated their attention on microatoll growth and sedimentary features related to the living communities around the sand cays. Charles Hoskin studied the distribution of grain size and mineral forms of calcium carbonate in the various facies of the entire atoll. Robert Folk and an assistant examined the sedimentation features of the sand cays with special consideration of the clastics and their distribution and orientation.

"The botanists, Conover and Perkins, measured the standing crop of the principle living plant communities by species population throughout the atoll along 10 transects. These data revealed the existence of a number of distinct community zones which reflect the growth character of the atoll. Results from this study provided an estimate of the living standing crop of benthic plants (not including the Zooxanthella in the polyp colonies), both non-calcareous and calcareous, with and without the lime incrustation by weight, in gms/m^2 species. It was discovered that the windward slope of the atoll was firmly cemented by an extensive mantle of encrusting coralline algae. There was no lithothamnion ridge community, but in its place a sparsely populated, unconsolidated subtidal platform composed of loose blocks, boulders, cobbles and smaller fractions of coral and algal rubble. Even in the lagoon no deep deposits of sand were observed since all types of bottom were subtended by coarse fragments of coral-algal rubble (unconsolidated), no matter where the botanists drove in their coring tubes in the shoal waters. The nature of the deep channel bottoms may differ from these findings for shoal water facies. Also the features in the lagoons, reported in 1959 as patch reefs, were recognized as true faros, or microatolls, with similar growth features to the atoll's own characteristics. Benthic plant production is very high on the atoll, and contributes a large fraction of the calcium carbonate composing the

reef. An honest estimate of the amount of lime contributed by plants and animals in the living communities is one of the objectives of this study. Charles Hoskin is providing data on the subfossil and fossil estimates based on sediment analysis. Dr. Bonet intends to obtain a deep core from Alacran in the near future to provide additional data.

"Incidental to the major objectives, the nature of growth of micro-atolls or faros was investigated by the botanists. High temperatures and widely fluctuating salinities in the microlagoons of the faros suggested one possible reason for the scant life in these shallow sand-filled basins. The natural growth and death cycle related to age of the communities has been suggested as another reason. The exhaustion of nutrients in these small systems is another. Further studies on microatoll growth characteristics will be undertaken in the summer of 1961. It is believed that a shallow, faro-choked lagoon such as that at Alacran and in the Maldives atolls, may be related to the possible high transport rate by wind driven currents. These provide high nutrient levels, oxygenation, and perhaps warmth in winter (air temperatures go to freezing some days during the passage of a "norther" over Alacran) and cooling in summer provided by the exchange, as well as furnish spores and polyp larvae for seeding.

"Collections were made by Perkins of 5 representatives of the Phaeophyta at daily intervals over a month to study the lunar periodicity of their reproductive cycles on Alacran.

"Over 430 field numbers of benthic plants, a number of plankton tows, (which were surprisingly rich) and dredged samples from the bank in 35 fathoms of water were obtained during the five week survey.

"Data were obtained at each station (quadrat) including salinity, temperature, light (in ft candles), turbidity, depth and notes on the sedimentation features."

Participants were as follows:

Geologists: William Behrens, Fernando Bonet, Donald Boyd, Glen Cosh, Augustus Cotera, Robert L. Folk, Miles Hayes, Charles Hoskin, Edward Klován, Louis S. Kornicker, Walter Pusey, Thomas Wright, and Amado Yanez; Botanists: John T. Conover, Laura Huerta M., and William Dana Perkins. Institutions represented were the University of Mexico, Instituto de Geologia, Mexico, University of Texas, University of Wyoming, Columbia University, Instituto Polytecnico, Mexico, Rice Institute, Rutgers University, and the University of Rhode Island.

Dr. Brian Logan, of Texas A. & M., visited Alacran, as well as the other cays on the Campeche Shelf, in February, 1960, in the course of his work on the Pleistocene history of the Campeche Shelf.

The summer of 1961 saw a continuation of work on Alacran, with several parties in the field. Dr. Bonet, with his assistant, Sr. Yanez, and a party of drillers, drilled a hole through several hundred feet of sediments on Perez Islet. Dr. Charles Hoskin, with Prof. Don Winston and Harold Illich, made sedimentation studies and collected marine animals. Dr. John T. Conover, Prof. Harold Humm, Bruce Welch, and K. M. S.

Aziz studied algae and marine ecology. F. R. Fosberg made a brief survey of terrestrial ecological features and vegetation, as well as a collection of plants, with the object of comparing Alacran with Pacific atolls. Of special interest was the opportunity to compare present vegetation with that recorded in 1899 by Millspaugh. Change has been extreme.

The Atolls off British Honduras:

Until last summer among the least known atolls in the world were Turneffe, Lighthouse, and Glover's reefs, off the coast of British Honduras. In 1960 and again in 1961 these were visited by David Stoddart, of the Geography Department, Cambridge University. Detailed maps were made of many of the cays as well as collections of the plants growing on them. The processes of physiographic change were studied. A general report, mentioning briefly this work, as well as a popular book (see Recent Literature below), was issued on the 1959-60 Cambridge University Expedition. Detailed reports are expected. Meanwhile, Hurricane Hattie has swept these atolls. It is hoped that Mr. Stoddart will be able to return and compare the present physiography with his detailed maps, and further elucidate the role of hurricanes in shaping the cays.

Recent Literature

Two new journals of interest to the Coral Atoll Program have recently been launched. One of these is a quarterly called Pacific Insects, published by the Bishop Museum and edited by J. Linsley Gressitt. It includes systematic papers on insects of the Pacific Basin, some of which undoubtedly will treat atoll forms. None of the papers in the first number (1959) seem to record any atoll species. We have not seen the later numbers, though at least two volumes have appeared to date. An adjunct series to Pacific Insects, Pacific Insects Monographs, "devoted to monographs and other works too large for the journal", will be issued irregularly. Two numbers have appeared, the second of which (1961) is a review paper by Dr. Gressitt on Problems in the Zoogeography of Pacific and Antarctic Insects. This has a direct bearing on the insects of the Pacific coral atolls and an appendix by Miss Setsuko Nakata contains a record of a phasmid from Ebon Atoll.

Of the series, Insects of Micronesia, published under the same auspices, and containing many records of atoll insects, some parts of volumes, including two introductory volumes and 38 systematic treatments, have appeared to date.

The second journal is Cahiers du Pacifique, published at the Muséum National d'Histoire Naturelle, Paris, to contain material in all scientific and cultural fields touching the Pacific and lands bordering it. The Cahiers appear at irregular intervals, and of the three numbers published so far all contain articles of interest to students of coral atolls. The first number (Dec. 1958) has a paper on coral islands in the Tuamotus by Gilbert Ranson and a bibliography relative to coral in the Pacific for 1957-1958. In the second (June 1960) is a detailed history

of Clipperton Island, by M.-H. Sachet, including a comprehensive bibliography of works relating to or mentioning this easternmost atoll in the Pacific. In the third number (June 1961) are a summary of modern oceanographic researches in the South Pacific by Michel Legand and an article on the Great Barrier Reef and the Capricorn Group by P.-H. Fischer. In the latter are a map and description of Heron Island. In addition to original papers and review articles, each issue contains reviews of recent publications, news of the Pacific, and bibliographies on special subjects.

Next to the Great Barrier Reef of Australia, the reef complex of New Caledonia is perhaps the most important in the world, and it had so far remained rather poorly known. It is a pleasure to report that an extensive program of study of this reef has now been initiated by the French and is actively being pursued. Details are given in no. 3 of *Cahiers du Pacifique*.

We wish again to call attention to The Elepaio, Journal of the Hawaiian Audubon Society, and to emphasize that this little publication is becoming a major place of publication for information on atoll ecology, especially that of the Hawaiian atolls. In recent numbers E. P. Wilson describes the situation on Midway, which he visited in company with Chandler Robbins who was checking on results of the Navy's efforts to reduce the gooney bird hazard to aircraft; W. R. Smythe writes about monk seals on Laysan; Charles Hanson reports observations on Midway, with especial reference to the trouble between the Navy and the albatrosses; Richard Warner discusses Midway and Laysan in an article on the present status of the avifauna of the Hawaiian Islands; and Hubert and Mable Frings contribute a long article entitled Problems of Albatrosses and Men on Midway Islands. Here, in non-technical language, is a substantial amount of information on atoll ecology, and especially on the distressing situation on Midway discussed above.

Natural history of Ifaluk Atoll: Physical environment, by Joshua I. Tracey, Donald P. Abbott, and Ted Arnow, B. P. Bishop Museum Bull. 222: 1-75, 1961. This, the first of the series of reports of the Pacific Science Board Ifaluk Expedition, in 1953, is a fine piece of work. It includes a short description of the atoll, with photographs, followed by chapters on the physical environment and on the geology and hydrology. Under physical environment, climate and tides are discussed--thus this chapter heading refers to the environment of, rather than on, the atoll. Under geology and hydrology are sections on the geology of the islands, hydrology, reefs and lagoons, and a summary of geologic history. All of these subjects are treated in substantial detail, and well illustrated by photos, diagrams and maps. Separate large geological and sedimentary maps, and cross sections are provided. The detailed logs of the wells dug for an investigation of the hydrology provide much information on the soils which are briefly discussed. Very considerable attention is paid to the nature and material of the sediments, with descriptions and histograms showing the size, distribution and biological origin of the major constituents. No chemical analyses are reported. Earlier stands of the sea and changes in the outline, area and position of the islets are discussed at length. In most respects the information presented will provide an admirable basis for comparison with similar data from other atolls. This volume will certainly serve for a long time as a model, and for an indication of what can be accomplished in a relatively short visit to an atoll.

Dr. T. Goreau has written a short paper (Endeavour 20: 32-39, 1961) summarizing current knowledge and describing his own work on the mechanisms of calcium deposition and the role of zooxanthellae or endozoöic algae in reef corals. The work was done on Jamaica reefs rather than on atoll reefs, but is of extreme importance in understanding reef ecology. It also includes a short bibliography of pertinent papers of a more technical nature.

In a paper on The role of algae in the formation of beach rock in certain islands of the Caribbean, Robert W. Krauss and Raymond A. Gallo-way conclude that algae play no direct role in the formation of this interesting rock, so characteristic of coral islands. They do not exclude the possibility of an indirect influence of algae in the process by means of their influence on carbon dioxide content of the water, or acidity. The paper appeared as Caribbean Beach Studies, Technical Report No. 11, Part E, from the Coastal Studies Institute, Louisiana State University, 49 pp., March 20, 1960. The distribution of these reports is unfortunately limited.

A major contribution to coral reef ecology has recently appeared, which stems in part from work initiated under the Pacific Science Board Coral Atoll Program, a paper by Robert W. Hiatt and Donald Strasburg on Ecological relationships of the fish fauna on coral reefs of the Marshall Islands (Ecol. Monogr. 30: 65-127, 1960). This brings together observations on the behavior, feeding habits, and stomach examinations of 233 species of reef-inhabiting fish collected on the Bikini Resurvey, the Arno expedition, and at the Eniwetok Laboratory, 2,051 fishes in all, 1,185 of them collected at Arno Atoll. In addition the observations of Randall on the Onotoa Expedition are extensively cited. After placing this enormous amount of data on record in systematic order, the authors arrange the fish and discuss them according to habitat groups, then list them according to trophic levels, and finally, diagram and briefly describe the food web in the Marshall Islands reef ecosystem. Thus, not only is there presented here an impressive quantity of the raw materials of coral reef ecology, but the work constitutes an important step in the generalization of such information.

From Dr. George Scheer we have received three papers, two of them reporting results of the Xarifa expeditions, concerning the developmental history of stony corals, the other on the history of coral research, with a considerable bibliography. One of the papers is in Die Naturwissenschaften 10: 238-239, 1960, the others in Bericht 1958/59 Naturwiss. Verein Darmstadt 37-67, 1959.

Early attempts of Mormon missionaries to establish their church in southeast Polynesia, including the Tuamotus are described by Professor S. G. Ellsworth in a booklet entitled Zion in Paradise (1-35, Logan, Utah, 1959). Dr. Ellsworth, Associate Professor of history at Utah State University, is carrying on studies of the diaries of early Mormon missionaries in the Pacific, and we expect that this is only the first of many additions to literature on the atolls visited by these hardy people.

A brochure entitled Coastal Geography (anonymous, unnumbered, 17 pp., National Academy of Sciences--National Research Council, 1961) embodies the report of a Conference on Coastal Geography, held by an ad hoc

panel under the auspices of the NAS-NRC Committee on Geography, March 20-21, 1961. A very interesting program of research on coastal problems was proposed, but work on coral atolls was not mentioned; yet, because of the geographical nature of atolls, all problems involving them would seem to be coastal.

Harry Ladd has brilliantly summarized, for the non-specialist, current ideas and research on the geology and marine ecology of reefs and atolls in a well illustrated article entitled Reef Building (Science 134: 703-715, 1961). Results of the Eniwetok drilling are emphasized, with a cross sectional diagram, and a proposal for deep drilling on Midway Island is described, with a discussion of its significance. Mention should also be made of a paper by Ladd on the Origin of the Pacific Island Molluscan Fauna (Am. Jour. Sci. 258-A: 137-150, 1960), which has profound implications for the paleogeography and biogeography of the Pacific. His main thesis in this paper is that the Indo-Pacific marine fauna, instead of having originated in the Indonesian region and migrated into the Pacific may have originated in the Pacific and migrated into the Indonesian area.

Very worthy products of atoll investigations are popular books, that give the non-scientific public some insight into the hardships and hard work of expeditions, as well as the fascinations and satisfactions thereof. We saw this in Bates and Abbott's Coral Island. Now we have just received "From the Cam to the Cays", by David Carr and John Thorpe, an account of the Cambridge University Expedition to British Honduras, 1959-60, published by Putnam, London, 1961. This is a well written, well illustrated, and interesting account which makes good reading, and includes a chapter on Turneffe and Lighthouse atolls, which are little enough known and seldom visited by scientists. This chapter was written by our friend and correspondent David Stoddart, geographer from Cambridge University.

The greatest of all coral reefs, or rather, complexes of coral reefs, is the Great Barrier Reef of Australia, lining the Queensland Coast from Torres Strait to the Tropic of Capricorn. It has excited and intrigued the imagination of those interested in the sea and its beauties and mysteries since Captain Cook discovered it, became trapped in its maze of channels, and almost lost the tiny but famous Endeavour, in which he made his first voyage around the world. Many books have been written about this great reef, as well as innumerable scientific papers. The Great Barrier Reef Committee was organized by the Royal Geographical Society of Australasia to promote scientific investigations of it. The area includes about 200 flat coral islands or cays, some of which, such as Low Isles, have been carefully studied. The cays have much in common with the islets of oceanic atolls and their study sheds light on many ecological problems of atolls. On one of them, Heron Island, the Great Barrier Reef Committee maintains a laboratory, while on another, Green Island, there is an underwater observatory, providing excellent facilities for continuing study.

A magnificent introduction to this great ecological phenomenon has now been provided by Keith Gillett and Frank McNeill in, The Great Barrier Reef and Adjacent Isles, published by the Coral Press, Paddington, Sydney, Australia in 1959. This book of almost 200 pages describes the reef and

its islands in popular but accurate language, and is illustrated with magnificent photos. The main part, however, is devoted to descriptions and illustrations, many of them beautiful colored plates, of the animals likely to be found by visitors. After a visit to Heron Island, guided by this book, we can testify to its usefulness and readability.

We also welcome the appearance of Prof. Obermüller's beautifully illustrated work on the geology and mineralogy of Clipperton Island as one of two papers in a special volume entitled "Recherche géologique et minérale en Polynésie Française", Paris, 1959, published by L'Inspection Generale des Mines et de la Géologie. The other work in the same volume, by Professor Aubert de La Rue, deals with the high islands of the Society, Marquesas, and Austral Groups with only brief mention of their surrounding reefs. It contains a liberal series of the author's magnificent photos, including a good one of beachrock.

Attention of atoll students is directed to a series of "library summaries" and "library brochures" on Pacific island and Pacific area geography, and other subjects of geographical interest in the Pacific, prepared for the Pacific Missile Range, Point Mugu, Calif., under the direction and editorial supervision of Dr. William L. Thomas, Jr., of the Geography Dept., University of California, Riverside, Calif. This series, of which we have seen 27 booklets, issued between July 1960, and January 1961, is difficult to refer to, as the booklets are not numbered, no publisher is indicated, and no mention is made of where or whether they are available or to whom. They do not bear any indication of security classification, however.

Each booklet contains a summary of available published information, with liberal quotations from sources which are listed in a bibliography. The work seems to be competently done, under the authorship of one or more compilers for each booklet, well organized, and clearly presented in offset reproduction, with maps and photos. In addition to a number of high islands, the following atolls are treated either by summaries or brochures: Taongi, (Pokak) Kapingamarangi, Cocos (Keeling), Majuro, Eniwetok, Johnston, Wake, Canton, and Midway. The only apparent difference between a summary and a brochure seems to be that the latter is regarded as more complete.

Matters of general interest

The outstanding recent scientific event in the Pacific area has been the Pacific Science Congress, held in Honolulu in August 1961. Although no programs were devoted specifically to coral atoll problems, many of the symposia and contributed papers touched on or had an important bearing on these problems. Notable among these were symposia on Man's Place in the Island Ecosystem, Pacific Basin Biogeography, Modification of Biotic Balance of Island Faunas and Floras, Plants and the Migrations of Pacific Peoples, Land Tenure in the Pacific, and Pacific Island Terraces: Eustatic? The published papers of these symposia will appear in due course either in the proceedings of the Congress or in appropriate journals. Some abstracts are available in the volume entitled Abstracts of Symposium Papers, distributed at the beginning of the Congress.

In the annual report for 1959 of the Institut de Recherches pour les Huiles et Oleagineux (IRHO), p. 20, is an announcement of the establishment on Rangiroa Atoll of a coconut experiment station with a staff of a director and two professional scientists. A paper entitled The improvement of the coconut palm production on the atolls of the Tropical Pacific was presented by Y. Fremond of the IRHO, in the Tropical Crops Improvement symposium at the Tenth Pacific Science Congress, dealing with the work and plans of this station. We await with interest the results of these investigations on the culture of this important atoll crop.

We are informed that Dr. Herold Wiens' massive work of integration of knowledge on coral atolls, written during the last several years as a major step in the Pacific Science Board's Coral Atoll Program, will soon be published by Yale University Press. It should enable us to view the field and to determine what should be done next.

Bulletin readers may be interested to know that an International Society of Tropical Ecology has recently been organized, under the leadership of Indian ecologists, to promote research and training in tropical ecology and to improve communication among those interested in the subject in different parts of the world. An inaugural meeting was held in January 1960, at Bombay, India, on the occasion of the Indian Science Congress; reports of the meeting were published in the first number of the society's Bulletin. This Bulletin is published at irregular intervals and two numbers have appeared so far. Books and monographs also may be published later. Membership is open to all who are interested in tropical ecology; the society is to be represented by vice presidents and national committees in countries other than India. Correspondence should be addressed c/o Central Botanical Laboratory, 10 Chatham Lines, Allahabad, India. Fees and dues are: admission \$2.00 U. S. or 0/15/0 Sterling; individual membership \$5.00 or 1/15/0; institutional membership \$7.00 or 2/10/0; life membership \$70.00 or 25/0/0; applications and checks should be sent to the treasurer. In America correspondence may be addressed to and checks made out to F. R. Fosberg, senior vice president and U. S. representative (Pacific Vegetation Project, % National Research Council, Washington 25, D. C.). Those interested in coral atoll ecology are cordially invited to join.

Errata in Bull. 74, Birds of the Gilbert and Ellice Islands Colony
by Peter Child

- p. 3, par. 1, line 11: instead of "last-names" read "last named".
- p. 4, line 2: instead of "Peter's" read "Peters".
- p. 4, last-but-one paragraph, line 2: instead of "of" read "or".
- p. 4, last-but-one paragraph, line 2: instead of "bikeman" read "Bikeman".
- p. 13, under 12 Sula sula: instead of "Keta" read "Kota".
- p. 23, last paragraph, line 3: instead of "freedly offered" read "freely offered".
- p. 31, line 4: instead of "thousand" read "thousands".

